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A COMPARISON OF RUTTING BEHAVIOR OF ASPHALT CONCRETE UNDER THE F-4C/G AND F-15C/D AIRCRAFT

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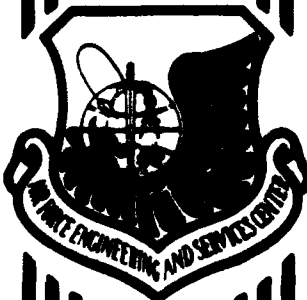HARBERT HALL
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The purpose of this investigation was to compare the effect of the F-4 and the F-15 aircraft on rutting performance of standard airfield bituminous mixtures during hot weather conditions. The comparisons and conclusions herein were drawn from trafficking new 4 inch asphalt concrete overlying 12 inches of Portland cement concrete. The asphalt concrete was produced from AC-30 asphalt cement and 100 percent crushed limestone of 3/4 inch maximum size. Pavement surface temperatures ranged from 80 F to 122 F during traffic.

Both test strips were trafficked simultaneously, back and forth, in a channelized manner 6,000 times by loadcarts that simulated the heaviest designs of F-4 and F-15 aircraft. In one strip, the F-4 loadcart test wheel was loaded to 27.1 kips with cold tire inflation pressures of 265 psi. In the other strip, the F-15 loadcart test wheel was loaded to 30.5 kips with cold tire inflation pressure of 355 psi. Continued on reverse.

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It was learned that it takes 5,000 passes of the F-4 to produce a 0.4 inch rut depth in this particular mix, but only 1,000 passes of the F-15. This rut depth of 0.4 inch was far from failure of the layer and was the maximum reached in the F-4 test strip. The dominant mode of rutting was densification with plastic flow of the mixture estimated to have caused about 12 percent of the rutting.

The differential rutting between test strips might have been larger had the mixtures been the same. This can be hypothesized, with 95 percent confidence, from the significant differences in such characteristics as initial mat densities of the 5 foot offset cores, which were higher in the F-15 test strip; and initial mat VMA, binder content, and percent passing the number 8 sieve which were higher in the F-4 strip.

It was recommended that another full-scale experiment be run to determine if a change in the mix or density requirement could possibly improve performance. The new sections should include optimum binder content at Marshall Compaction and at gyratory compaction. The latter would reduce the amount of binder from that of conventional design but may make highly compacted sections feasible.

PREFACE

This report has been reviewed by the Public Affairs Officer (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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I. INTRODUCTION

Background

The Air Force Problem with Rutting

On today's military airfield the most likely pavement feature to rut is the primary taxiway. Runways also rut, but because of the more severe loading conditions, rutting accumulates much faster on taxiways. Here aircraft traffic is slower and more channelized than on the runway. On the average, every 6 passes of a fighter aircraft results in contact between the tire and a point on the taxiway that represents the centerline of the wheel path for the aircraft. On the taxiway, aircraft speeds usually average about 17 mph, ranging from 5 mph for a towed craft up to 25 mph. When taxi speeds are this slow and the pass-to-coverage ratio is as low as 6, two of the conditions that increase the likelihood of bituminous pavements rutting occur.

At normal taxi speeds, a dichotomy exists: the same aircraft that is moving so slowly as to cause rutting is moving too slowly to be seriously affected by the rutting. In other words, on the taxiway, rutting will not normally cause loss of control of the aircraft nor will it cause intolerable vibration. The aircraft is traveling too

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slowly for its performance to be much affected by pavement rutting. However, situations sometimes exist where even minimal taxiway rutting might affect performance of aircraft. This could occur when aircraft are turning on a wet or frozen taxiway pavement or when aircraft are taking off from the taxiway. At normal taxiing speeds, rutting has to be quite severe (subjectively speaking, more than 2 inches deep) to degrade the performance of the taxiing aircraft.

If aircraft can perform on taxiways in the presence of rutting, albeit with reduced efficiency, why is the Air Force so concerned with rutting? The answer is that rutting can deteriorate the pavement to the point that the aircraft itself is threatened with damage. In fact, this pavement deterioration can progress to the point that the taxiway ceases to function altogether. Often, when rut depths approach 1 inch, serious signs of pavement distress, such as longitudinal cracking appears. These cracks may degenerate into alligator cracking which can accelerate further deterioration of the pavement. Eventually, small chunks of pavement and aggregate pop loose and lie on the surface. The main concern of those who operate the aircraft is that a tire or exhaust will loft these loose particles into the air, for ingestion by following jet engines. Maintenance personnel commonly hold that one small pebble could and occasionally does destroy million-

dollar jet engines. Another operator concern is that loose pieces of pavement will be crossed by the high pressure tires, causing cuts and occasional blowouts.

Further, standing water in ruts will initiate structural problems. The concern of the pavement engineer is that water will enter the pavement, reducing layer bonding, increasing stripping or soften the subgrade and require premature repair or replacement. Standing water can also freeze in the rut where it could cause loss of control of the aircraft or freeze in the pavement where it could reduce the densities of the layers. Repair of a primary taxiway, brought about by rutting, can require that the entire airfield be closed.

So, of the pavements on the military airfield, the taxiway is the most likely to rut. Although excessive rutting has some short-term impacts on the function of aircraft, operation can continue on taxiways with reduced efficiency. The more immediate concern is accelerated deterioration of the pavement, which can incapacitate an aircraft or close down an entire airfield for months.

Higher Tire Pressures are Introduced

When the heavyweight F-15C/D aircraft began service, engineers became concerned that bituminous airfield pavements would rut prematurely. Premature rutting has been referred to by Carpenter and Freeman (1) as failure within the first year or two after construction (an extreme

example might be failure caused by a single load), as contrasted to the gradual appearance of rutting under long term traffic. These new single-wheel loadings were 30,500 lbs on tires with 355 psi inflation pressure.

The new aircraft was built by adding weight to the F-15A/B without changing the wheel design; tire inflation pressure was increased commensurately in order to maintain the tire vertical deflection at 30 percent. All this resulted in increased pressures over a slightly reduced area of contact between the load and the pavement. The main concern caused by the introduction of the F-15C/D was that the primary taxiways, where the traffic is slow and almost channelized, would rut enough to cause maintenance and airfield shutdown problems.

Objective

The purpose of this investigation was to compare the effect of the F-4 and the F-15 aircraft on rutting performance of standard airfield bituminous mixtures during hot weather conditions.

Scope

This study concentrated on the fully-trafficked portion of two pavement strips that were part of a test conducted by the Air Force Engineering Services Center Laboratory in the fall of 1986 to investigate the rutting of standard airfield bituminous mixtures. One mode of

rutting was defined as the maximum permanent vertical displacement of the pavement surface from its original configuration due to densification. Another mode of rutting was defined as the total apparent rut depth due to all causes. Hot weather conditions were defined as those conditions producing pavement surface temperatures equal to or greater than $80^{\circ}F$.

The comparisons and conclusions herein were drawn from trafficking new 4-inch asphalt concrete overlying 12 inches of Portland cement concrete. The asphalt concrete was produced from AC-30 asphalt cement and 100 percent crushed limestone of 3/4-inch maximum size. The sections were simultaneously trafficked up to 6000 passes by the F-4 and F-15 aircraft. Pavement surface temperatures ranged from $80^{\circ}F$ to $122^{\circ}F$ and averaged $102^{\circ}F$ during traffic.

II. LITERATURE REVIEW

Rutting Mechanism

Bituminous concrete is a particulate mixture. Its total volume contains a solid, semi-solid and gas. When properly proportioned, it forms a matrix that is comprised of aggregate that has been cemented with asphalt, leaving just enough air voids to allow a limited amount of densification under traffic without squeezing the asphalt out onto the surface. Airfield mixtures restrict air voids to 5 percent maximum, which is intended to limit this densification so that rutting by consolidation does not occur. In these cases, the particles are free to rotate and the internal friction (in the areas of the particle to particle contacts) develops the strength to carry the load, stopping the consolidation of the mix before ruts form. While excessive air voids lead to rutting by densification, insufficient air voids lead to rutting by plastic flow. If insufficient air voids are present, the load-carrying capacity of the mix, which depends on characteristics of the aggregate, cannot come into play because of too much of the low-viscosity asphalt. Plastic flow usually is not the dominant mode of rutting unless the air voids are below 3 percent. Here, the material moves under traffic but does

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not densify. Instead, the material may even decrease in density, failing in shear and exhibiting heaving of the pavement surface parallel to the rut.

There is another mechanism, besides aggregate friction, whereby pavements carry loads. When a load is applied rapidly to a bituminous pavement or applied to a cool pavement, and the voids in total mix are sufficiently low, it is possible to transmit the load to the binder. The cementing action of the asphalt provides the strength to carry the load (2). Foster thinks this binding strength to be almost equal to that of Portland cement (2). However, these loading conditions are not germane to this study, which is concerned with loads that are applied to bituminous pavements slowly or under hot weather conditions when the cement has very little strength.

Densification

In their study of the stress-history effects on behavior of cohesionless soils, Lade and Duncan (3) hypothesized that elastic strain is determined primarily by the elastic deformations of individual particles, but plastic strain results from sliding of the particles. Harr points out that stress is extremely variable within soil or aggregate matrices; that it exists in particulates only at points of contact which comprise a small fraction of the volume of the aggregate; and that stress distribution should be handled in a stochastic manner. Here, enormous

stresses produce moments in the aggregate, causing the more mobile ones to rotate and slide into a denser state (4). Since researchers have shown that very little of material deformation is elastic, it can be concluded from Lade and Duncan's hypothesis that very few of the stresses on an aggregate cause deformation of the individual particle, and that the mechanism responsible for the material deformation is the relative movement of particles. This densification of the material is not recoverable and results in rutting.

Now, if the material is a mixture of aggregate and asphalt, in the warmer months or under slowly applied loads, decreasing asphalt viscosity or creep will increase the binder's effectiveness as a lubricant, permitting further densification under loadings of traffic. If the asphalt is viscous enough at the start, its lubricating effects may be small and have less effect on the mix densification.

Plastic Flow

The most important contributor to plastic flow (loss of stability) has been identified as air voids less than 3 percent of the mix volume (2). In this condition, the asphalt fills almost all the voids and the mix is analogous to an almost saturated soil under pressure. Contact between aggregate is lost and some of the applied load is transferred from the aggregate to the asphalt. Since the cement cannot carry a load under warm

temperatures or at slow loading rates, the mix fails
rapidly.

There is another scenario, one where plastic flow
could occur at higher air void contents if the confining
stresses were lowered. This could occur if the pavement
layers were not fully bonded, allowing slip. Here, mix
strength is developed under the applied load by the
internal friction of particle to particle contact between
the aggregate. The capacity of the mix to develop strength
depends on the confining stress. In their treatise on
premature deformation in bituminous overlays of concrete
pavements, (1) Carpenter and Freeman maintained that
asphalt concrete overlaying concrete is much more likely to
fail than if overlaying flexible surfaces. The reason
given is that slip for poorly bonded interfaces is more
probable between layers of dissimiliar materials than
between two layers of similar materials. Any loss of bond
at the interface produces a decrease in the horizontal
principal stress (confining pressure), increasing the shear
stress state. The reduced confining pressure around the
loaded pavement, at the bottom of the overlay, allows
plastic flow to occur. As the material at the interface
moves outward, it shoves the adjacent material upward,
possibly causing it to loosen slightly.

Effect of Thickness of Mixture Overlaying PCC

In the Fall of 1985, prior to the test which is the subject of this study, comparisons of the F-4 and F-15 were conducted on an apron at Tyndall AFB using 2 and 4 inch bituminous overlays of concrete pavements. One observation from this study was that for both aircraft, magnitude of rutting was proportional to the layer thickness. The cause of this behavior may have been that the boundary effect of the underlying layer restricted particle movement more in the 2 inch layer than in the 4 inch layer. Carpenter and Freeman (1) state that this was because there was more material to undergo densification, and that the stresses which activated this permanent deformation were higher. In their work, they used the octahedral shear stress which they have found to be lower for thinner overlays than for thicker ones.

III. CONSTRUCTION

Test Sections

The Air Force wanted to compare the taxiway rutting that could be expected from the F-15C/D with that already occurring under its previous heavyweight fighter, the F-4C/G. Unfortunately, there was no current analytical model that could accurately predict rutting of airfield pavements. The approach to the problem, as in similar situations in the past when new aircraft went into service, was to construct and traffic test sections to compare the rutting effect of the unknown to the more familiar. Since the F-4C/G aircraft had previously been regarded as having the most severe single-wheel load in service, it was selected as the point of reference. For the sake of brevity, the two aircraft will be referred to as the F-4 and the F-15 in the rest of this paper.

Two test strips (12 feet wide by 300 feet long) of 4-inch asphalt concrete were placed on 12 inches of Portland cement concrete (Figure 1). Air Force personnel produced the mix on site and performed all construction with Air Force equipment. The mix design, quality control, and all measurements were the responsibility of The New Mexico Engineering and Research Institute (NMERI). Each test

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Sta 2+68

Sta 2+38

F-15 ANALYSIS

F-4 ANALYSIS

F-15 STD MIX

12' X 300' TEST STRIP (TYPICAL OF 5)

F-4 STD MIX

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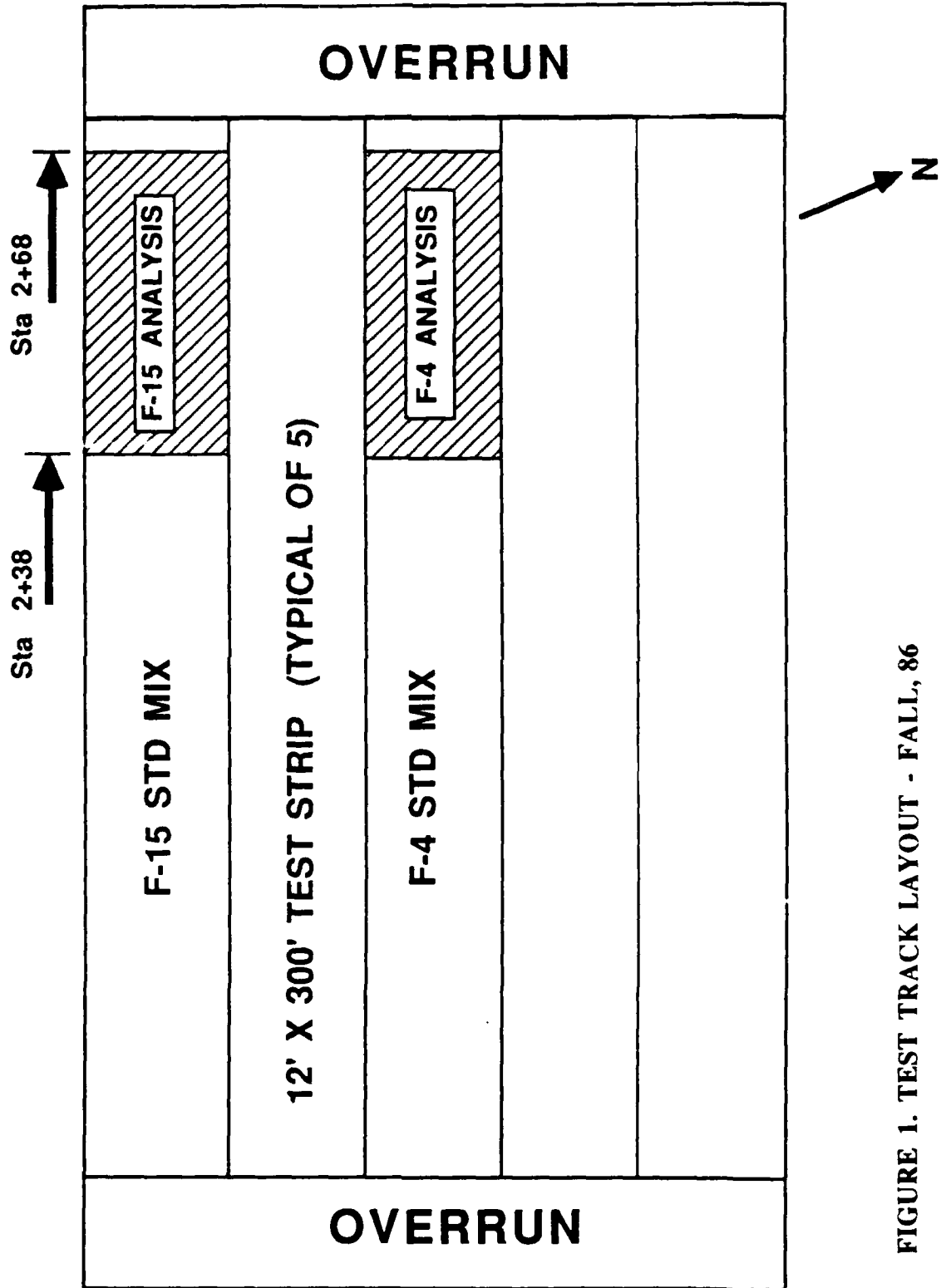
FIGURE 1. TEST TRACK LAYOUT - FALL, 86

strip consisted of 6 or 7 truckloads of mix, each containing 10 to 12 two-ton batches. The mix was compacted with a vibratory roller. The Portland cement concrete was intended to provide uniformity of support, precluding the additional effects of variable base support. A detailed description of the construction has been reported by Pavlovich and Stonex (5).

Mix

Both test strips were paved with standard airfield mix which contains 3/4-inch maximum size aggregate (6). All aggregate were crushed limestone, except a bagged mineral filler was used to supply additional -200 dust. Microscopic examination of the filler at 4000x magnification showed it to be quite irregular in shape. The mixture was designed using Air Force Manual 89-3, Materials Testing, Marshall method. An AC-30 binder was used. The Job Mix Formula (JMF) aggregate gradation was derived from the plant bins output and is shown in Table 1. The optimum binder content was 4.8 percent, by weight of mix (Appendix D1-D5). This was arbitrarily adjusted upward to 5.3 percent to lower the air voids. The mix design was documented by Pavlovich and Stonex (5).

Table 1

Job Mix Formula and Tolerances

Parameter	JMF	AFM 88-6 (6)
Stability	2840	1800 (min)
Flow	13	16 (max)
VTM	4	3-5
VF	75	70-80
% Lab Density	99% of 155.8	99 +- 1.1%
Binder Content	5.3% (wgt mix)	JMF +- 0.2%

Note: Binder content optimum was 4.8 percent. The JMF was arbitrarily increased to improve voids (5).

IV. THE TEST PLAN

Sections Sampled

Since the objective of the test was to compare standard airfield mix performance under the two aircraft, the sections receiving the highest number of traffic applications were analyzed; these same sections showed the widest variation in rut depth between strips. The test section layout is shown in Figure 1 with the areas receiving the most traffic denoted by hatching.

Rutting Factors

In this experiment, the factors that induced rutting (load and number of passes) were classified as controlled factors and the uncontrolled factors were temperature, variation in mix quality and measurement error.

The last 11 observation stations in each test strip (Figure 2) received the full 6000 passes of traffic. Nine of these in the F-4 strip and eight in the F-15 strip were arbitrarily selected to serve as replications for analysis of the load, traffic, and mix effects on rut depth.
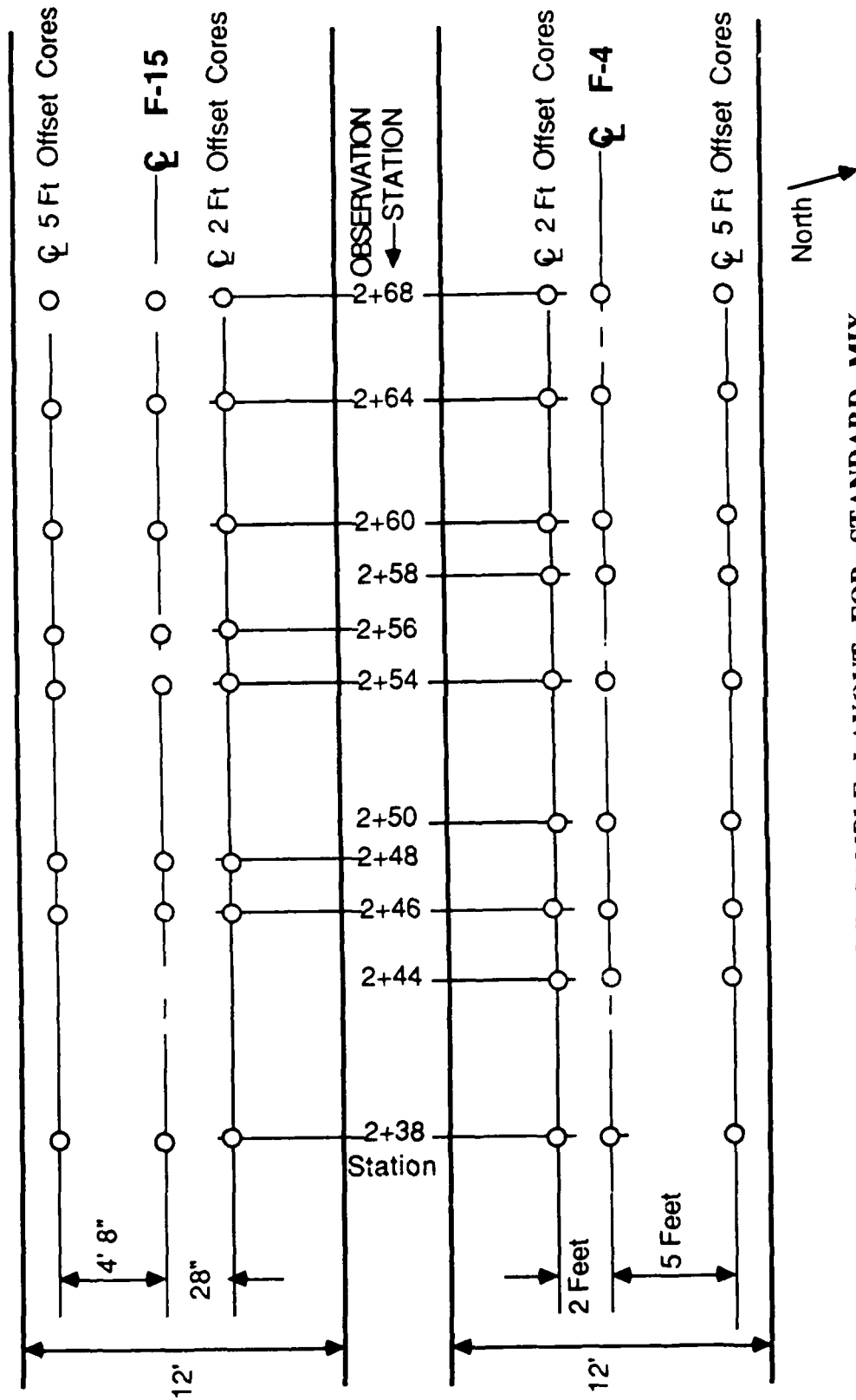
FIGURE 2. CORE SAMPLE LAYOUT FOR STANDARD MIX

Control Factors

Control factors in this analysis were 2 levels of load, and 19 levels of traffic.

Load

The term "load" included the weight on the tire, the tire inflation pressure, and the characteristics of the tire, all of which resulted in contact pressure on the pavement peculiar to each aircraft. Hence load was considered to be represented by the term "aircraft."

Since each test strip was trafficked by only one aircraft, the load variation as a factor affecting rut depth could be removed by studying the within-test-strip effects. Conversely, load effects were studied by examining the between-test-strip effects. The main portion of this experiment was concerned with the study of load effects on rut depth development.

Traffic

Rut depth was observed at 19 levels of traffic at all 17 observation stations in the two test strips shown in Figure 2. The variation of rut depth due to traffic was analyzed under two sets of conditions; constant pass levels (within pass level) which removed traffic as a source of variation, and varying pass levels (between pass levels) to observe traffic effects on rut depth.

One aspect of traffic, speed of the loadcart, was not measured or controlled. The braking at the ends of the test strip and acceleration during startup after reversing direction had an indeterminable effect on rut depth variation within each strip. Between-strip variation of speed was also probable due to frequent exchange of drivers in the F-15 loadcart. These factors were assumed to be negligible. It was estimated that both loadcart speeds were about 8 mph when averaged over the whole strip for the entire test.

Uncontrolled Factors

Other factors that could have affected the pavement rutting performance include temperature, mix quality, and measurement error.

Temperature

High service temperatures contribute to rutting by reducing the viscosity of the mix binder. The magnitude of the effect depends on the temperature susceptibility of the binder and, of course, the pavement temperature. In the Tyndall test, the temperature factor was blocked by trafficking the F-4 and F-15 at the same time. But for the purpose of qualitatively comparing the performance of these two test strips with other full-scale tests, temperature was measured at various pavement depths for each traffic increment (Appendix A3). The surface temperature of the

pavement is shown in Figure 3, averaged for each interval during which traffic was applied.

Mix quality

The term, mix quality, refers to how well the constructed pavement's mix characteristics such as internal voids, density, percent of laboratory compaction, binder content, and gradation conform to those of the JMF. The values of samples taken from test strips were expected to remain within the tolerances that were listed in Table 1. Mix samples were obtained from cores taken from the mat. Variation of the above characteristics within and between test strips and deviation from the JMF were used to define quality of the constructed mix. Variation was measured by the coefficient of variation and the significance of mixture deviations from the JMF was evaluated by the Student's t-test.

Error of measurement

To average out the measurement error, all observations were taken over the entirety of both test strips by the same individuals with the same equipment at approximately the same time for each pass level. A profilograph that was manufactured by Rainhart was used for the rut measurements. The measurements consisted of a real-time reproduction of the rut shape on a scaled paper grid,
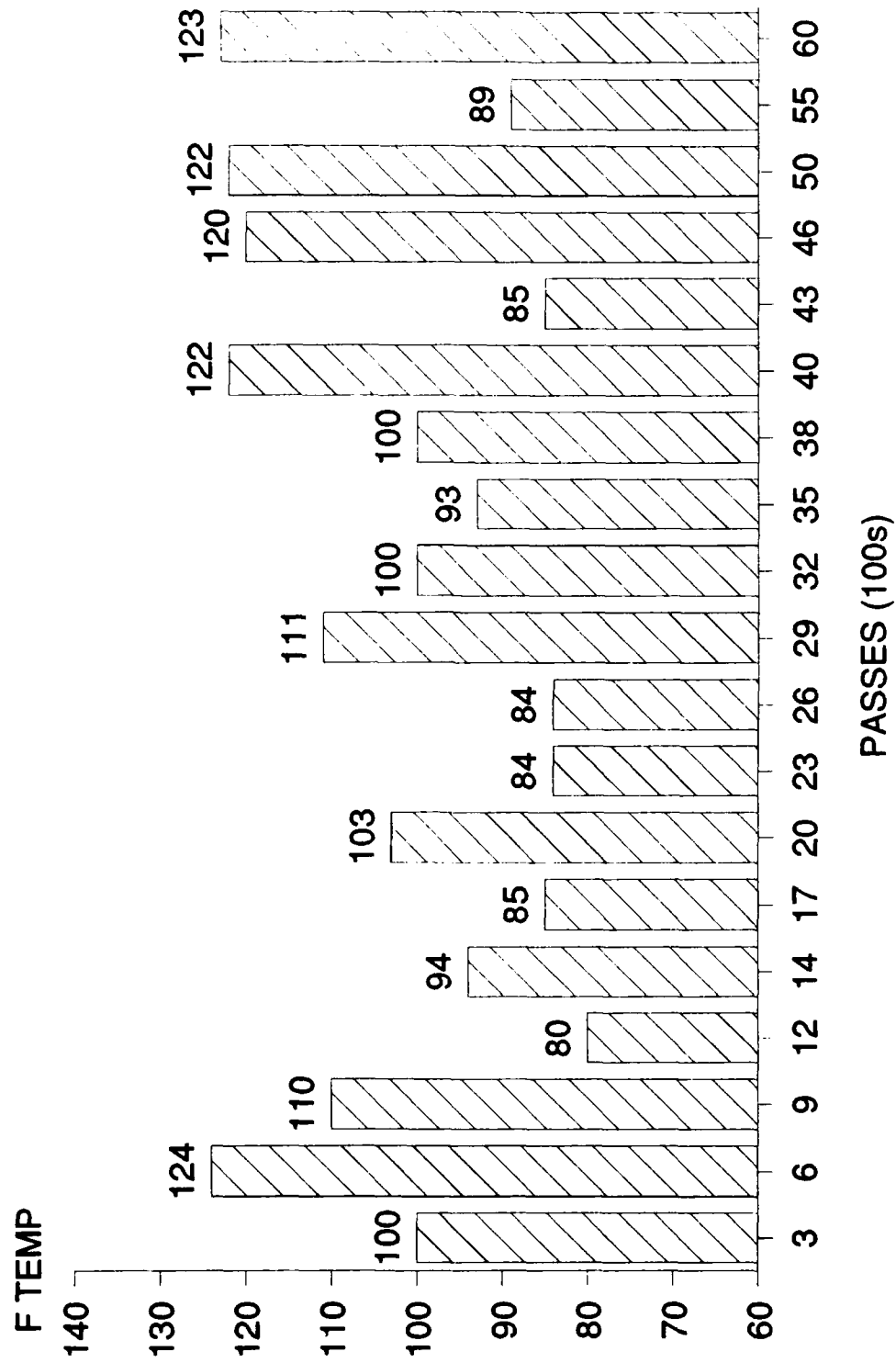
FIGURE 3. AVG PAVEMENT SURFACE TEMPERATURE DURING TRAFFIC

as a rolling wheel traversed the surface of the rut cross-section. The rut depths were manually scaled directly from these profiles of the rut surface.

Conduct of the Experiment

Simultaneous trafficking of the 2 test strips started September 4, 1986 and was halted on October 2, after 6000 passes. A detailed description of the test procedure has been prepared by Pavlovich and Stonex (7).

Both test strips were trafficked at the same time, back and forth, in an almost channelized manner by loadcarts that modeled the heaviest designs of F-4 and F-15 aircraft. In this study, the application of maximum stress from a wheel load onto a point in the pavement was defined as a coverage. If the contact pressure between the tire and pavement was assumed to be uniform and equal to the tire pressure, then the tire simultaneously applied a coverage to a number of points on the pavement across the entire width of its footprint with each pass.

The widths of the ruts that developed were about twice the widths of the respective tire footprints. The assumption was made that 95 percent of the loadcart passes were entirely within the ruts. This meant that the loadwheel centerline had been restricted to an interval that straddled the rut and measured plus or minus half of the footprint width (in order for the outside edges of the loadwheel to be confined within the rut) 95 percent of the

time. More importantly, this also meant that the rut center received coverage by some portion of the tire 95 times out of every 100 times that the loadcart passed. Therefore, the 6000 passes that were applied could be said to be equivalent to about 0.95 x 6000 = 5700 coverages.

In one strip, the F-4 loadcart test wheel was loaded to 27.1 kips with cold tire inflation pressures of 265 +- 20 pounds per square inch. In the other strip, the F-15 loadcart test wheel was loaded to 30.5 kips with cold tire inflation pressures of 355 +- 20 pounds per square inch.

Loadcart speeds initially averaged about 8 mph. However, they began to slow as the test strip lengths grew progressively shorter, as explained in the following paragraphs. The loadcarts were stopped at the ends of the test strips to reverse direction.

The plan was to apply 300 passes (load increments actually varied from 200 to 500 passes) and then measure the rut parameters with a transverse profilograph at prescribed observation stations. The geometric references for the profilograph were 24-inch offsets, on each side of the rut centerline, well inside the wheel tracks of the loadcart drive wheels. Of the 29 observation stations for measuring rut depth, only stations 19 through 29, the westernmost stations of each test strip, received the full 6000 passes. This portion of both test strips comprises

this study and is shown in Figure 2 with the coring layout from which the samples were taken.

Collection of Data

Rut Measurements

In Figure 4 the maximum permanent vertical displacement of the pavement surface from its original configuration was defined as Rl. Total displacement amplitude of the pavement surface (R2) was assumed to be comprised of densification and plastic flow. Since there was very little plastic flow observed in this test, rutting was depicted by Rl in the graphics throughout this report. The vertical difference between the surface profiles that were taken before applying any traffic and the profiles after traffic was used to determine these rut depths.

All rut measurements were obtained by profilograph as described in the preceeding paragraph on the conduct of the test. To check for possible changes in the ruts due to relief of stresses, 17 of the 22 observation stations that received the full 6000 passes were cross-sectioned with rod and level after a period of one year following trafficking.

Mix Sampling

After all trafficking was complete, cores were taken at certain stations identified in Figure 2; eight stations in the F-15 strip and nine in the F-4 strip. Three cores were extracted from the mat at each station; one from the
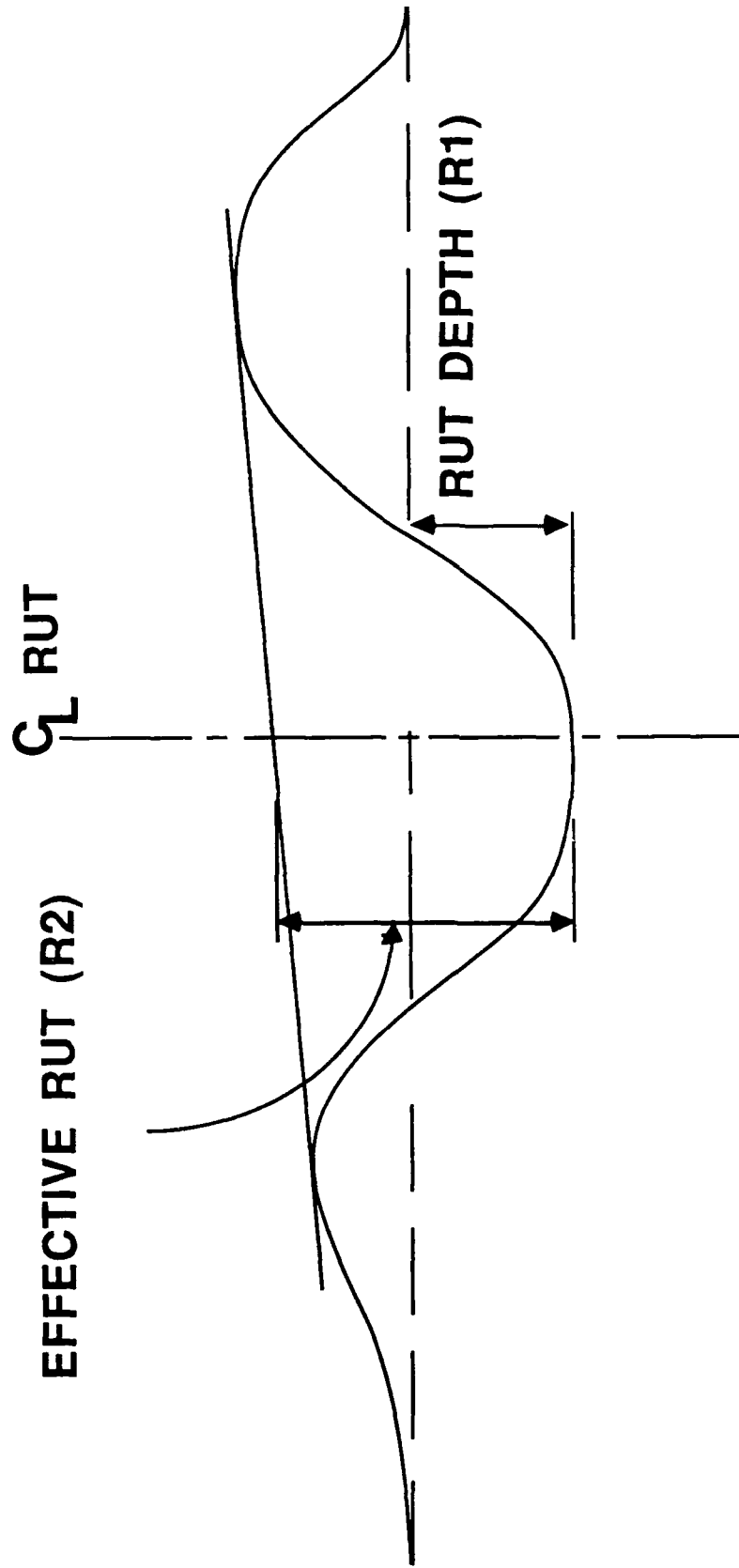
Figure 4.   DEFINITIONS OF RUTTING

rut, one approximately 2 feet off one side of the rut centerline, and one approximately 5 feet off the opposite side of the rut centerline. The cores were removed with an electrically powered, portable drill; water was used for cooling the bit. These cores from the two test strips were used to characterize the mixture.

Mix Characterization Tests

From each core, the mat bulk density was obtained and the voids in total mix (VTM), voids in mineral aggregate (VMA), and voids filled with asphalt (VF) were computed. For each observation station, core material was recompacted into three Marshall specimens to serve as reference densities. Core material left over from the recompactions was used to determine the representative asphalt content (AC), theoretical maximum density (TMD), and 3 parameters of the aggregate for each observation station.

The three aggregate parameters used to characterize the mixture are designated in Manual MS-22 by The Asphalt Institute as: the percent of aggregate passing the number 8 sieve (-8), which represented the fine aggregate fraction; the percent of aggregate passing the number 30 sieve (-30), which represented the mineral filler fraction; and the percent of aggregate passing the number 200 sieve (-200), which represented the mineral dust.

In-place density

The cores were brought into the laboratory to measure the weights in water and saturated-surface-dry, then oven-dried for 24 hours before weighing in air. All tests were in accordance with ASTM D2726 for specimens containing moisture.

Sample preparation

The cores were then heated until soft enough to remove all visible traces of the sawed surface. The tack coat was scraped off and all embedded aggregate that had been damaged by the core barrel was removed. These damaged portions of the core were then wasted.

All three cores from each station were then pulled apart, mixed, quartered and enough material removed to produce 3 recompacted Marshall specimens. The remaining material was used for extraction.

Recompacted Marshall specimens

Baseline laboratory densities for the material from each station were established by recompacting the material at 250°F with a manual Marshall hammer applying 75 blows on each face.

After air-cooling overnight, the specimens were then weighed in air, in water, and again in air (wiped dry for the 2nd weighing), all in accordance with ASTM D2726 for dry specimens.

Extractions

Extractions were performed in accordance with ASTM
D2172, Alternate Method A. The extract was run through an
SMM type high-speed centrifuge (10000 rpm) to recapture
most of the -200 material that had managed to penetrate the
filter employed with the first centrifuge.

Gradation

The aggregate recovered from the extraction was
sieved to get the Grain Size Distribution. Dry sieve
analyses, ASTM C136-84A, Sieve Analysis of Fine and Coarse
Aggregate, were used since the clean-appearing aggregate
did not seem to require washing.

Gravities

The bulk and maximum specific gravities and voids
parameters were computed, using apparent specific gravities
of the aggregate fractions. Pavlovich and Stonex (5)
provided the specific gravity of the asphalt and
aggregate.

V. TEST RESULTS

Rut Measurements

Rut depth measurements taken at nine observation stations in the F-4 test strip and eight in the F-15 strip are shown in Appendix A1 and A2, respectively. Since the rut depth at Station 2+64 after 900 passes was missing for both test strips, Station 2+62 measurements were used.

Cross-sections of the ruts that were obtained by profilograph are found in Appendices B1 and B2. The sections obtained with rod and level are shown in Appendices B3 and B4. The profilographs were 4 feet long and the levels extended 9 to 11 feet across the rut. Comparison of the rod and level readings one year after traffic with profilograph readings that were taken immediately following completion of traffic showed no visible change in the rut cross-sections for the 4-foot length profiled. Similarly, levels of the longitudinal profiles of both test strips produced the same profiles as levels taken immediately following traffic, despite 4 seasons without traffic.

Traffic Effect (Performance Within Test Strip)

The materials included in each test strip were designed to be uniform. If the asphalt mixture had been

uniform over the test strip, the expected rutting behavior would have also been uniform between observation stations. A within-strip study investigated the respective variation of rut depth and the rate of rutting within each test strip at constant and varying traffic levels.

Within pass levels (constant traffic)

The traffic variable was eliminated as an effect by analyzing the data at specific pass levels. These conditions of single-pass levels would also remove the temperature variable altogether since all the observation stations received each pass at the same pavement surface temperature.

Charts of rut depth vs observation station are displayed for each test strip at pass levels of 900 and 6000 on Figures 5 and 6. It is notable from these figures that the patterns established after only 900 passes continued throughout the 6000 passes.

Between pass levels (varying traffic)

The rutting behavior of the observation stations within each test strip were grouped into a family of curves and shown in Figures 7 and 8. The highly variable rutting behavior that is shown in Figure 8 implied that the material in the F-15 strip exhibited non-uniform rutting behavior at all traffic levels. The curves did not appear
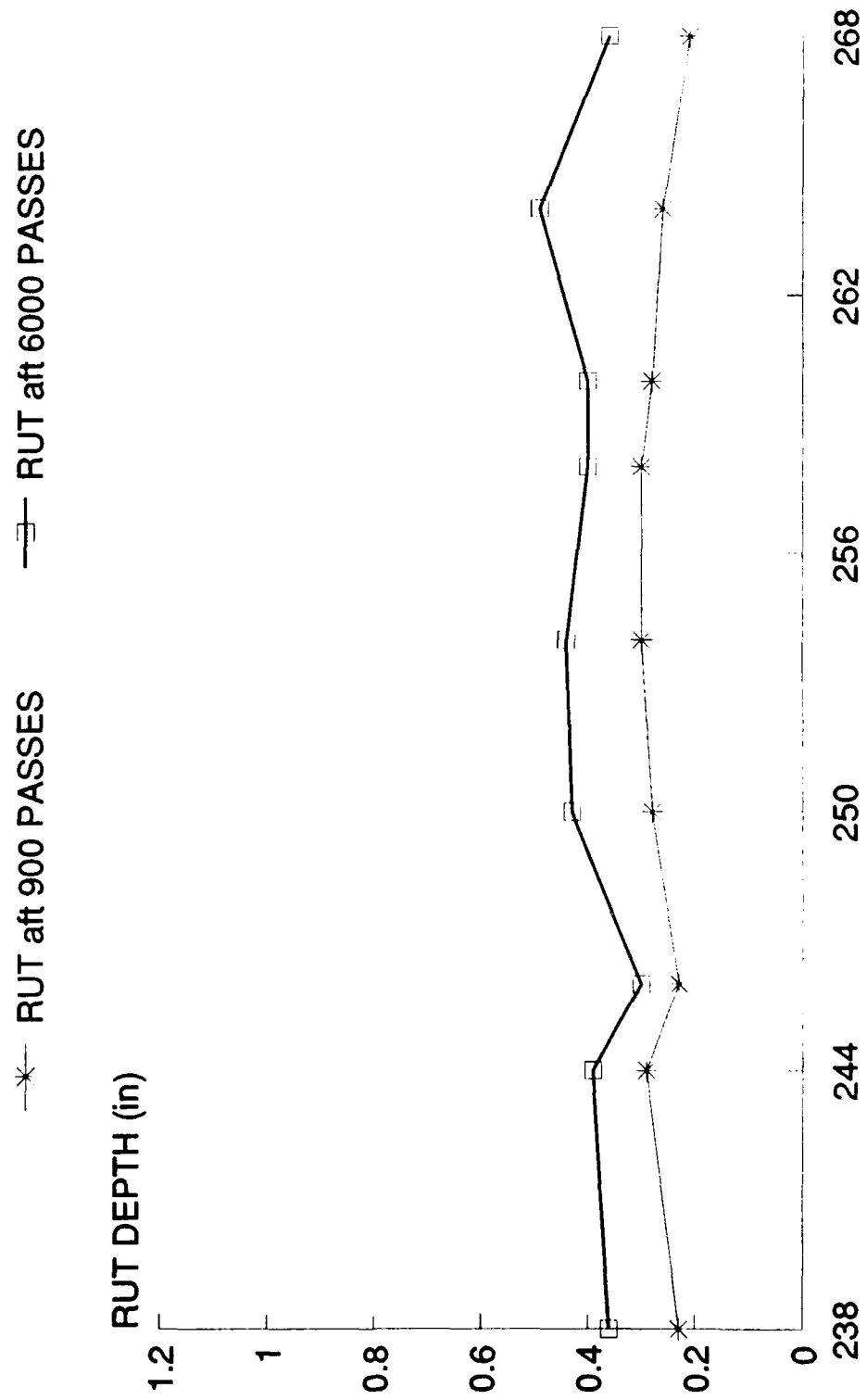
FIGURE 5. F-4 RUT DEPTH AT 9 OBS STATIONS
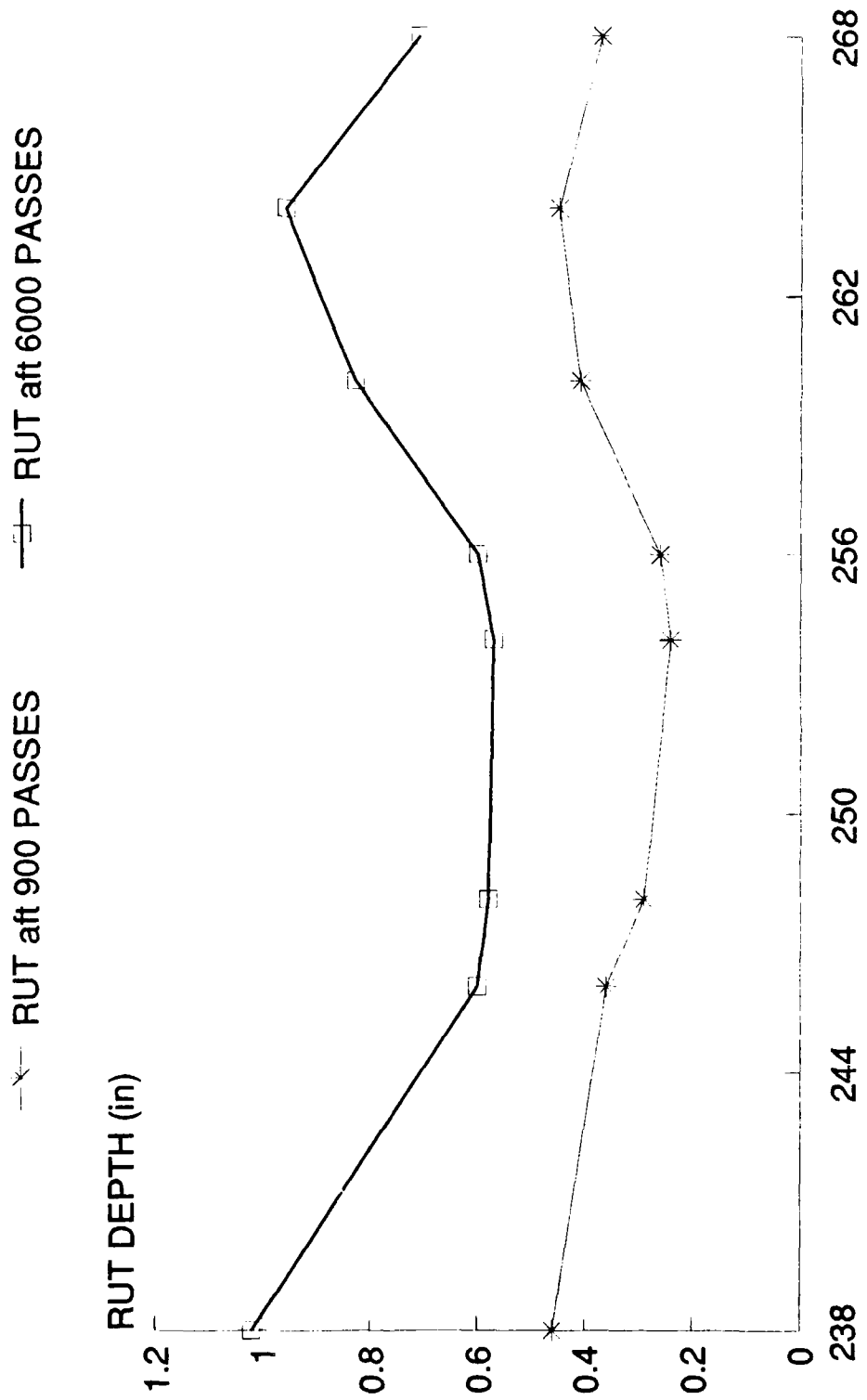
FIGURE 6. F-15 RUT DEPTH AT 8 OBS STATIONS

32
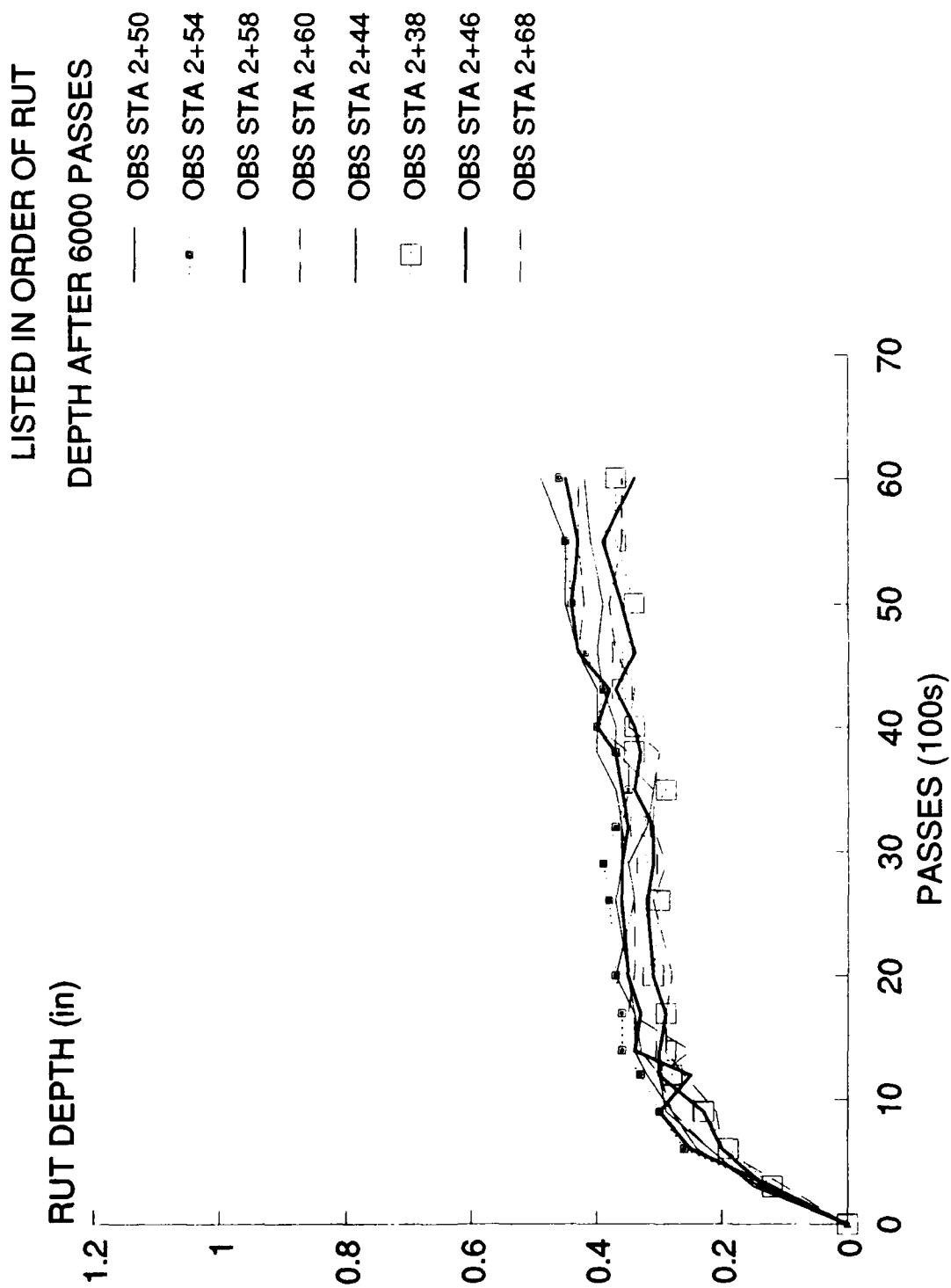
FIGURE 7. F-4 RUT PROGRESSION WITH TRAFFIC

33
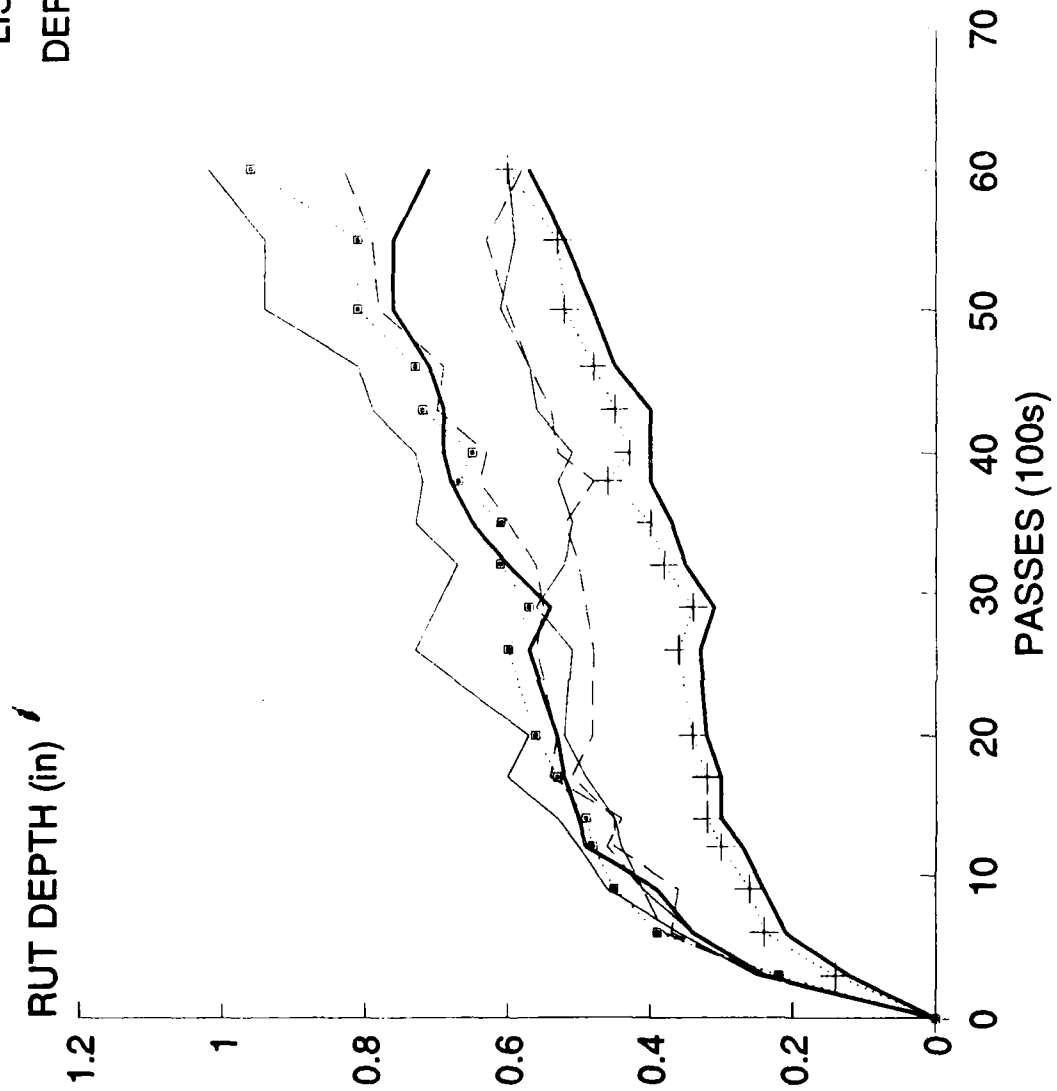
FIGURE 8. F-15 RUT PROGRESSION WITH TRAFFIC

to exhibit any common patterns such as coinciding low or high amplitude that might indicate temperature effects.

Load Effect (Performance Between Test Strips)

Each pass of traffic with the F-4 and F-15 loadcarts was applied to the 2 test strips at the same time. Therefore, temperatures of the pavements were the same for both test strips and clearly were not a factor in this study of load effects. Therefore, the only additional factor to be considered, above those used in the study of rutting behavior within test strips, was the aircraft difference.

The mean rut depth with traffic, for both the F-4 and F-15 test strips, are displayed in Figure 9, along with their respective standard errors of the mean. This chart showed:(1) the average rut depth of the F-15 is larger; (2) the differential rut depth between strips is increasing throughout the test; and(3) the standard error of the mean (SE) of the F-15 test strip is about four times that of the F-4 strip. The computed values can be found in Appendices A1 and A2. Figure 10 shows that the differential rutting between aircraft was a generally increasing trend with no signs of slackening throughout the application of traffic. For the mixture trafficked, the curve indicates the additional rut depth to be expected from the F-15 over that of the F-4.
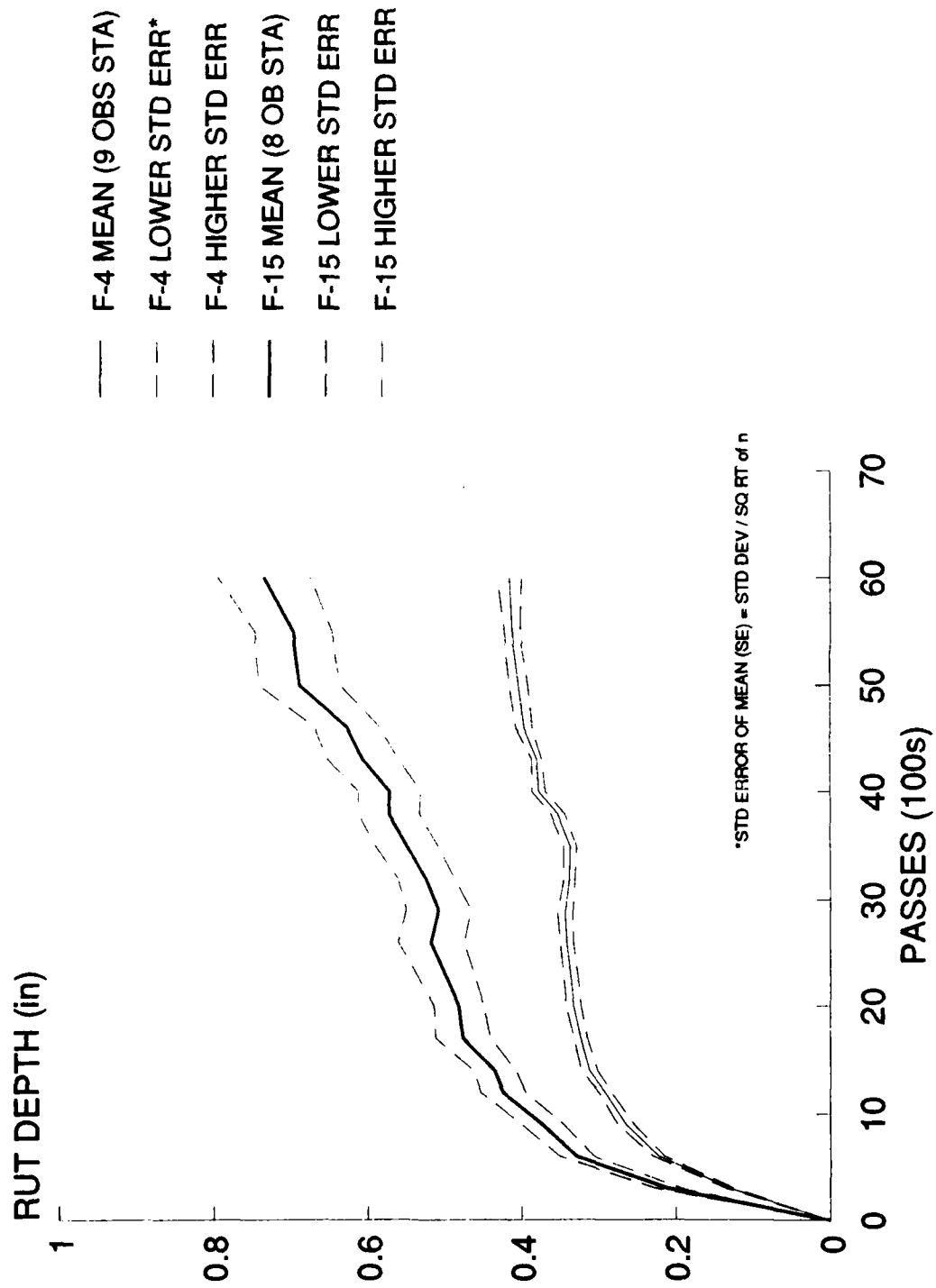
FIGURE 9. F4 AND F15 MEAN RUT PROGRESSION WITH TRAFFIC
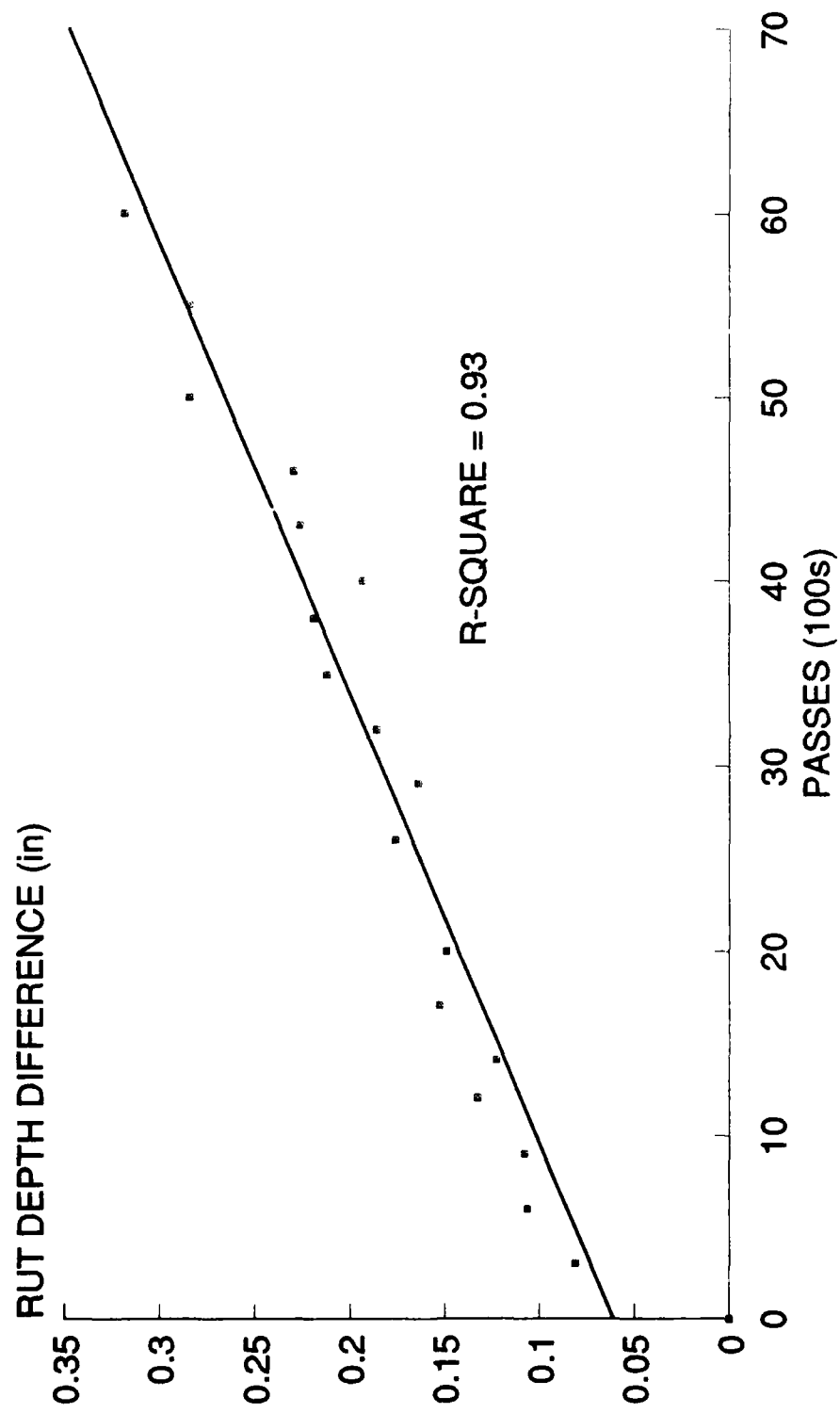
FIGURE 10. DIFFERENTIAL MEAN RUT BETWEEN LANES WITH TRAFFIC

Mix Quality Effect

The physical properties of both the cores taken from the two test strips and the specimens from laboratory recompactions are shown in Appendix Cl. Extraction and gradation data from the cores are shown in Appendices C2 and C3, respectively. Table 2 contains a summary of the properties from cores that represent each of the 17 stations examined in the two test strips after 6000 passes. The percent binder and gradation in Table 2 represent mixtures of the 3 combined cores taken from the mat at each station, and the weights and volumes are from each of 3 individual values. The voids parameters were calculated, using apparent specific gravity. The table of mix properties also shows the mean, standard deviation and coefficient of variation of mix properties determined from cores taken from all observation stations in each test strip.

Also shown in Table 2 are the F-test (Fisher Test) results along with the table percentile values representing the critical ratio of variances at a 5 percent significance level. When the absolute value of the computed ratio does not exceed the table value, the null hypothesis is sustained that there was no significant difference in the variances of the two test strips. Table 2 also compared test strip means using the computed Student's t-test vs the standard table values for a 2-tailed alpha of 5 percent

TABLE 2

MIX PROPERTY SUMMARY AS DETERMINED FROM CORES (FILE: myders5.cal)

LOAD STA	PROFILOGRAPH RUT After 6000 PASSES			CORE DENSITY			RECOMPACTED CORES			CORE DENSITY AS A % of RECOMPACTED LAB DENSITY			VTM			% AC
	R1	R2	R1/R2	OS 2'	OS 5'	RUT	DENSITY (pcf)	VTM (%)	VMA (%)	OS 2'	OS 5'	RUT	OS 2'	OS 5'	RUT	
1 2+38	.36	.41	.88	147.2	149.0	154.4	149.8	9.1	18.3	98.3	99.5	103.1	10.6	9.5	6.2	3.9
1 2+44	.39	.48	.81	150.0	150.9	155.2	149.2	9.4	18.6	100.5	101.1	104.0	8.9	8.9	5.7	3.9
1 2+46	.3	.41	.73	147.9	150.6	152.7	150.1	8.8	18.2	98.5	100.3	101.7	10.0	8.4	7.1	4.0
1 2+50	.43	.51	.84	150.4	151.9	157.2	151.5	7.7	17.5	99.3	100.3	103.8	8.3	7.4	4.1	4.2
1 2+54	.44	.48	.92	151.9	154.3	156.9	153.9	6.3	16.2	98.7	100.3	103.9	7.4	6.0	4.4	4.1
1 2+58	.4	.5	.80	150.1	151.1	155.7	153	7.2	16.5	98.1	98.9	101.8	8.9	8.1	5.5	3.9
1 2+60	.4	.49	.82	150.4	152.1	155.0	151.5	7.8	17.2	99.1	100.2	102.1	8.5	7.5	5.7	4.0
1 2+64	.49	.53	.92	149.8	152.7	154.2	151.5	7.5	17.7	98.9	100.8	101.8	8.4	6.6	5.7	4.4
1 2+68	.36	.42	.86	149.0	152.7	151.7	150.9	8.2	17.8	98.7	100.5	100.5	9.3	6.6	7.6	4.1
2 2+38	1.02	1.12	.91	151.2	156.7	158.0	156.2	5.2	14.8	96.8	100.3	101.2	8.1	4.7	4.0	4.0
2 2+46	.6	.7	.86	154.2	156.3	160.0	154.7	6.4	15.5	99.7	101.0	103.4	6.5	5.2	3.0	3.3
2 2+48	.58	.7	.83	155.8	152.5	159.0	155.9	5.3	.15	99.9	100.6	102.0	5.5	4.9	3.3	4.0
2 2+54	.57	.63	.90	155.8	152.5	159.0	154.7	6.3	15.5	100.8	99.7	103.1	5.7	6.7	3.6	3.8
2 2+56	.6	.7	.86	155.5	153.8	159.0	154.2	6.6	15.8	100.8	98.8	102.1	5.7	6.7	3.6	3.8
2 2+60	.63	.93	.89	154.0	153.0	158.0	154.8	6.3	15.4	99.5	98.8	102.0	6.7	7.3	4.2	3.8
2 2+64	.96	.99	.97	150.2	153.0	157.5	154.4	6.9	15.5	97.3	99.1	102.0	9.3	7.6	4.9	3.5
2 2+68	.71	.84	.85	148.7	150.8	154.9	153.9	7.2	15.7	96.6	98.0	100.6	10.2	6.9	6.5	3.5
F-4 MEAN	.40	.47	.84	149.63	151.72	154.78	151.30	8.00	17.56	98.90	100.28	102.30	8.91	7.64	5.78	4.05
F-4 SD	.05	.04	.06	1.33	1.42	1.69	1.42	.93	.76	.67	.70	1.05	.89	1.00	1.06	.14
F-15 MEAN	.73	.83	.88	153.18	154.05	158.24	154.85	6.28	15.40	98.92	99.48	102.19	7.15	6.62	4.08	3.73
F-15 SD	.17	.16	.04	2.59	2.01	1.49	.75	.66	.32	1.63	.96	.92	1.73	1.41	1.07	.15
F-TEST	10.833	14.432	1.792	3.771	1.995	1.294	3.605	1.985	5.802	5.867	1.875	1.299	3.769	1.993	1.023	
Fo,.05,9	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	
t-TEST	5.415	6.031	1.687	3.478	2.722	4.491	6.531	4.452	7.770	.028	1.939	.229	2.594	1.702	3.293	
t15,.05	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	
t4,.05,9	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	
t-POOLED	2.303	2.303	2.279	2.298	2.292	2.282	2.272	2.278	2.269	2.300	2.292	2.282	2.298	2.292	2.286	
SIGNIF?	S	S	NS	S	S	S	S	S	S	NS	NS	NS	S	NS	S	S
F-4 CV	.13	.09	.07	.01	.01	.01	.01	.12	.04	.01	.01	.01	.10	.13	.18	.03
F-15 CV	.23	.20	.05	.02	.01	.01	.00	.11	.02	.02	.01	.01	.24	.21	.26	.04

Legend:
TMD: Theoretical Maximum Density. Calculated by combining all 3 cores at each station.
FA: Fine Aggregate, -#8 sieve; Measured by combining all 3 cores at each station.
MF: Mineral Filler, -#30 sieve; Measured by combining all 3 cores at each station.
MD: Mineral Dust, -#200 sieve; Measured by combining all 3 cores at each station.
VTM: % Voids in Total Mix; Calculated from Mix; Calculated from core density & apparent sp. gr.
VMA: % Voids in Mineral Aggregate. Calculated from individual measmt of core density.
VF: Percent Voids Filled. Calculated from individual measurement of core density.
AC: Percent Asphalt Cement. Measured by combining all 3 cores at each station.
Recompacted Density, VTM, VMA: Average of at least 3 Marshall specimens.
LOAD 1: F=40.G   LOAD 2: F=150.0

TABLE 2 (CONT)

MIX PROPERTY SUMMARY AS DETERMINED FROM CORES (FILE: mydens5.cal)

LOAD STA	VMA 05 2'	VMA 05 5'	VMA RUT	VF 05 2'	VF 05 5'	VF RUT	CALCULATED TMD	PERCENT of TMD 05 2'	05 5'	RUT	FA (-#8)	MF (-#30)	MD (-#200)	MD/AC	MD/MF
1 2+38	19.7	18.7	15.7	45.6	48.7	59.8	164.6	89.5	90.7	94.0	60	28	6.3	1.61	.23
1 2+44	18.2	17.7	15.3	50.5	52.1	61.9	164.6	91.1	91.7	94.3	59	28	6.1	1.55	.22
1 2+46	19.4	17.9	16.7	47.3	52.3	56.7	164.4	91.9	91.6	92.9	58	28	6.0	1.50	.21
1 2+50	18.2	17.3	16.7	53.7	55.9	70.6	164.4	91.7	91.6	92.9	67	36	10.9	2.61	.30
1 2+54	17.3	16.0	14.6	56.1	61.6	68.7	164.1	92.6	94.0	95.6	59	32	9.6	2.34	.28
1 2+58	18.1	17.4	15.0	56.5	52.8	63.0	164.7	91.2	91.9	94.6	65	34	9.6	2.46	.28
1 2+60	18.0	17.1	15.5	52.0	55.5	62.2	164.4	91.5	92.9	94.3	55	28	7.1	1.78	.26
1 2+64	18.6	17.1	16.2	54.5	60.7	64.4	163.5	91.6	93.4	94.3	61	31	8.0	1.83	.38
1 2+68	18.8	16.8	17.3	50.1	57.4	55.3	164.2	90.7	93.0	92.4	45	23	8.8	2.17	.30
2 2+38	18.8	16.8	13.8	53.1	66.2	70.2	164.5	91.9	95.2	96.0	48	28	8.4	2.13	.30
2 2+46	17.5	14.5	12.6	57.9	63.1	75.0	164.9	95.5	94.7	97.0	52	30	9.1	2.39	.27
2 2+48	15.1	14.6	13.3	64.5	66.0	74.5	164.4	94.8	95.1	95.7	53	31	8.5	2.12	.30
2 2+54	14.9	14.8	12.9	62.3	54.4	73.6	164.9	94.5	96.5	96.7	48	27	8.0	2.09	.32
2 2+56	15.1	16.7	13.1	61.3	57.2	71.9	164.9	94.3	92.5	96.4	49	27	8.1	2.12	.32
2 2+60	15.1	16.0	13.7	57.3	55.1	68.0	165.0	93.4	92.8	95.8	42	22	7.0	1.85	.32
2 2+64	17.7	16.4	13.8	47.0	52.4	63.6	165.6	90.7	92.4	96.1	33	19	6.1	1.71	.32
2 2+68	18.6	17.4	15.1	44.1	47.8	56.3	165.6	89.7	91.1	93.5	45	21	5.5	1.55	.26
F-4 MEAN	18.48	17.33	15.63	51.14	55.33	62.51	164.28	91.09	92.38	94.26	58.78	29.78	8.04	1.98	.27
F-4 SD	.70	.71	.90	3.17	4.01	4.73	.36	.89	.96	1.05	5.94	3.68	1.68	.40	.06
F-15 MEAN	16.31	15.83	13.54	55.94	57.78	69.14	164.98	92.85	93.39	95.90	46.88	25.63	7.59	1.99	.30
F-15 SD	1.33	1.00	.72	6.86	6.27	6.01	.41	1.76	1.38	1.07	4.70	4.12	1.18	.25	.02
F-TEST	3.612	2.014	1.581	4.677	2.440	1.614	1.342	3.881	2.088	1.032	1.596	1.258	2.034	2.422	7.225
Fo,.05,9	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390	3.390
t-TEST	4.140	3.541	5.314	1.812	.943	2.506	3.717	2.552	1.730	3.186	4.604	2.182	.654	.072	1.441
t15,.05	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306	2.306
t4,.05	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262	2.262
t-POOLED	2.297	2.293	2.280	2.299	2.294	2.290	2.288	2.298	2.262	2.286	2.280	2.262	2.278	2.276	2.266
SIGNIF?	S	S	S	NS	NS	NS	S	S	S	S	S	NS	NS	NS	NS
F-4 CV	.04	.04	.06	.06	.07	.08	.00	.01	.01	.01	.10	.12	.21	.20	.19
F-15 CV	.08	.06	.05	.12	.11	.09	.00	.02	.01	.01	.10	.16	.16	.13	.06

Legend:
TMD: Theoretical Maximum Density. Calculated by combining all 3 cores at each station.
FA: Fine Aggregate, -#8 sieve; Measured by combining all 3 cores at each station.
MF: Mineral Filler, -#30 sieve; Measured by combining all 3 cores at each station.
MD: Mineral Dust, -#200 sieve; Measured by combining all 3 cores at each station.
VTM: % Voids in Total Mix; Calculated from indivl measmt of core density & apparent sp. gr.
VMA: % Voids in Mineral Aggregate. Calculated from individual measmt of core density.
VF: Percent Voids Filled. Calculated from individual measmt of core density.
AC: Percent Asphalt Cement. Measured by combining all 3 cores at each station.
Recompacted Density, VTM, VMA: Average of at least 3 Marshall specimens.
LOAD 1: F-4C/G

significance. The computed t and table values were pooled
to account for the different variances and sample sizes
between the test strips, after Cochran (1964) (8). The
t-test is a measure of differences between the means of the
2 test strips and is used to determine whether or not the
differences are significant. On the bottom line of Table 2
"NS" means that the null hypothesis was sustained that
there was no significant difference between the means of
the two test strips and "S" means there were significant
differences.

Core densities

At all but one station, the cores taken from the rut
were denser than those taken outside the rut. At all but 3
stations, the cores offset 5 feet from the centerline of
the rut were denser than those taken 2 feet from the rut.
This is of special interest considering that the 5-feet
offset cores were near the edge of the mat where density is
generally more difficult to achieve (Figure 2).

The recompacted densities in Table 2 were very
similar to the mat densities determined from cores at the
5-foot offset. Aggregate with newly fractured faces
occurred in most core material that was recompacted.
Notably, almost no fractured aggregate was observed in the
cores taken from the mat, including the cores from the rut,
all of which had higher densities than their recompacted
counterparts. The explanation for this could be that the

Marshall mold's unyielding confinement (which is necessary to prevent failure of the specimen) is quite different from the confining stresses in the mat. Another explanation could be that the Marshall hammer impact is more severe than that of a vibratory roller.

Core extractions

The amount of mineral matter found in the extract was determined to be, on the average, equivalent to 1.26 percent of the total weight of mix (Appendix C2).

Extraction data is contained in Appendix C2 and summarized in Table 2. The mean binder content of the F-4 strip was significantly larger than that of the F-15 by 0.26 percent, by weight of mix. Even so, at 4.05 percent, the average binder content of the F-4 strip was 0.75 percent less than the optimum (4.8). The mean binder content of both lanes was 3.92 percent, 1.88 percent less than the JMF value of 5.3 percent.

Gradations

The only gradation parameter that was significantly different between the two strips was the fraction of aggregate passing the number 8 sieve (Table 2). However, the coefficients of variation (CV) of aggregate size parameters in both test strips were higher than the CV of most other mix parameters (Table 2), indicating poor control of gradation.

The gradation data is contained in Appendix C3. Figures 11-14 show the grain size distribution (GSD) curves for all observation stations in each of the respective test strips, along with the recommended Air Force specification limits for airfield mixes to be subjected to tire pressures greater than 100 psi (6). To examine the effects of gradation on rutting, the gradation curve of each core was classified according to whether it experienced higher or lower rutting after 6000 passes relative to the other stations within the test strip. The grouping was accomplished after a simple ranking of the available data according to the amount of rutting at the observation stations.

Figures 15 and 16 show the grain size distribution (GSD) curves for the stations having the most and least amount of rutting after 6000 passes for each of the test strips. The specification limits are again shown for reference. Comparison of Figures 15 and 16 reveal distinct differences between the gradations of the two test strips; the cores from the F-4 strip showed a hump in the grading curve between the number 4 and 8 sieves.

The GSD curve shapes for the observation stations experiencing the greatest and least rutting after 6000 passes within each of the test strips were similar. Unlike the very different curves between strips, the gradation curves alone (within strips) did not explain the differential rutting between the observation stations.
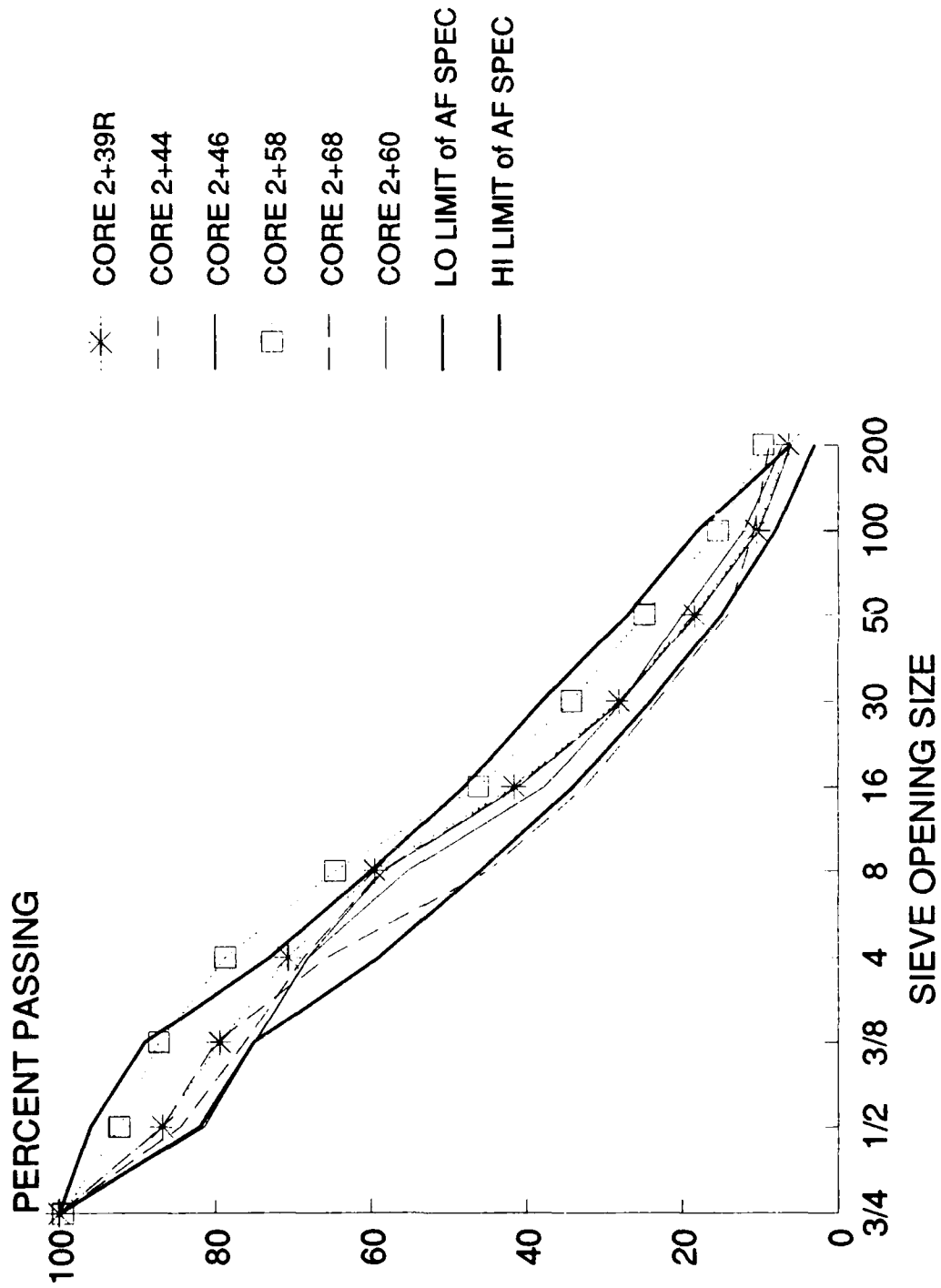
FIGURE 11. GSD OF OBS STAS WITH LOWEST RUTTING IN F-4 LANE
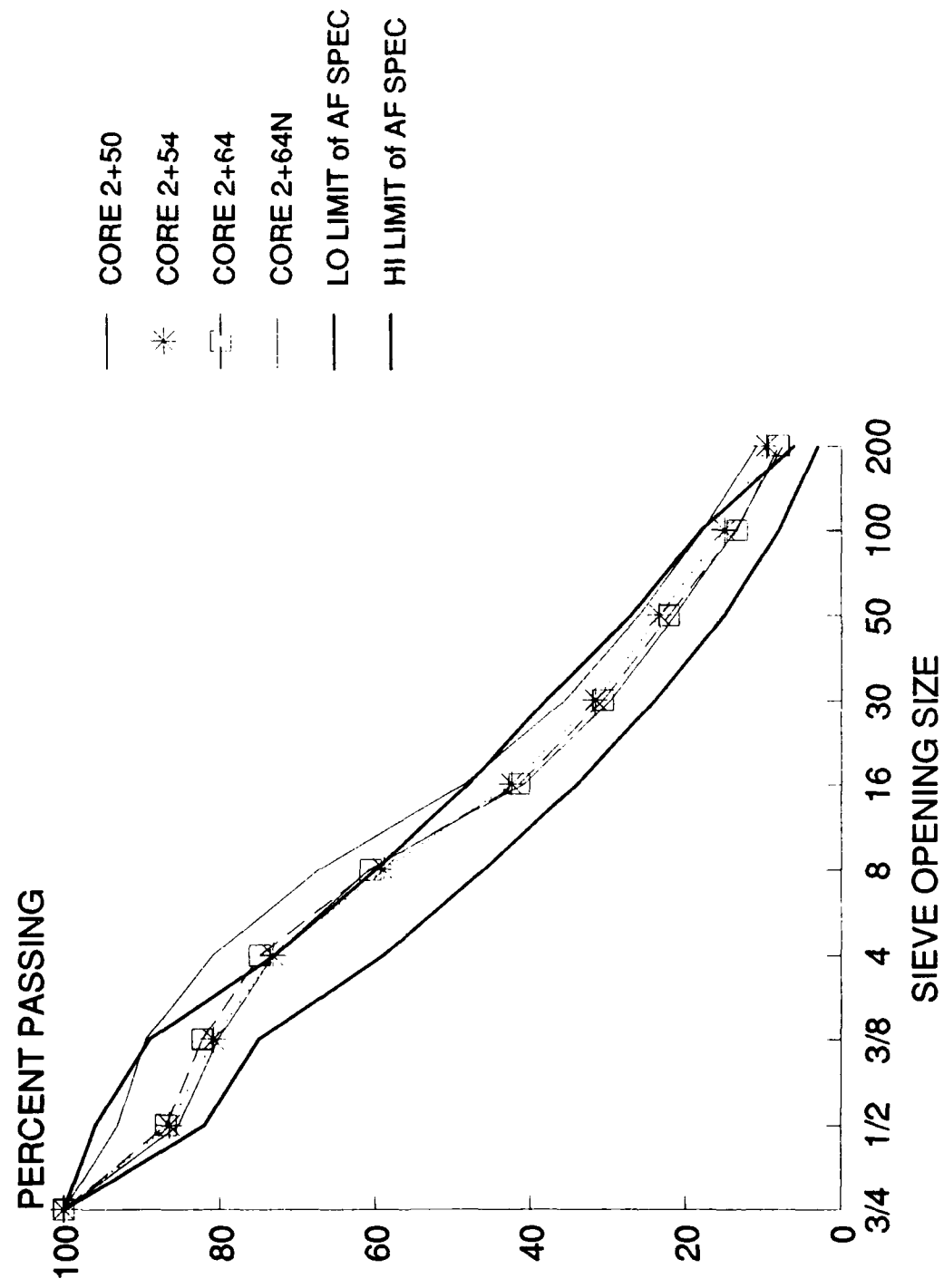
FIGURE 12. GSD OF OBS STAS WITH HIGHEST RUTTING IN F-4 LANE

PERCENT PASSING

CORE 2+45R

CORE 2+46N

CORE 2+48R

CORE 2+54

CORE 2+54N

CORE 2+56R

LO LIMIT of AF SPEC

HI LIMIT of AF SPEC

100

80

60

40

20

0

3/4 1/2 3/8 4 8 16 30 50 100 200

SIEVE SIZE
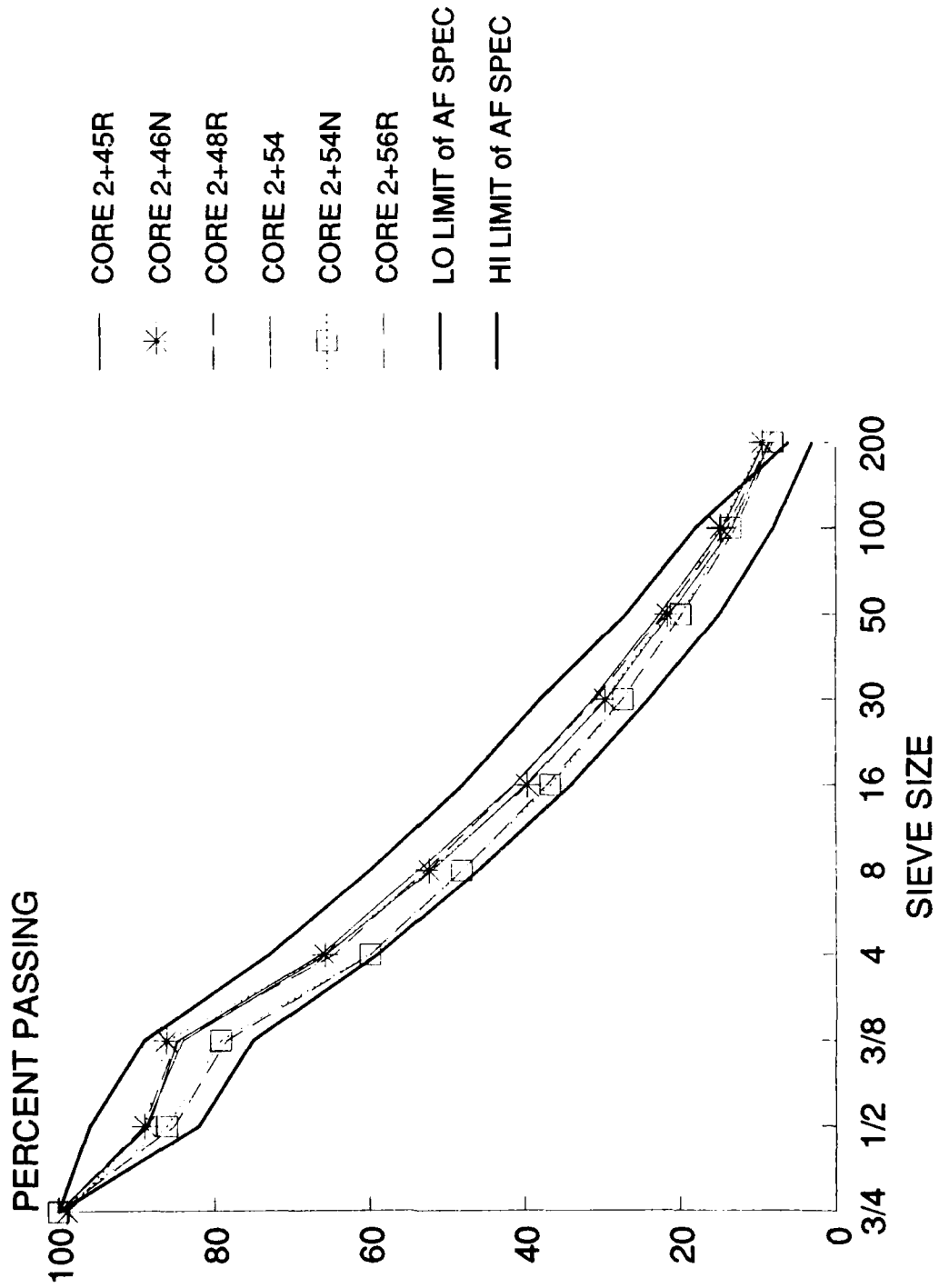
FIGURE 13. GSD OF OBS STAS WITH LOWEST RUTTING IN F-15 LANE
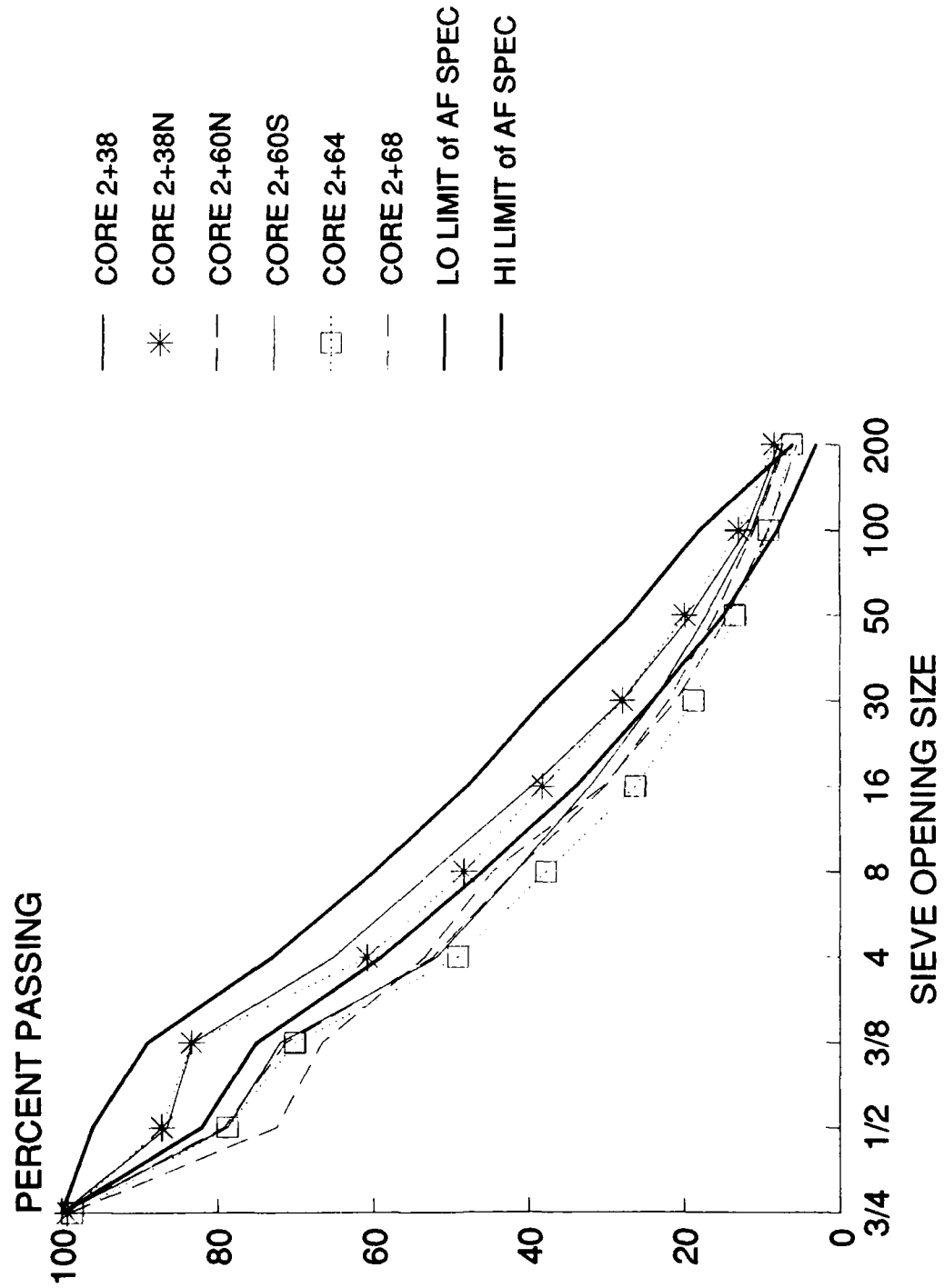
FIGURE 14. GSD OF OBS STAS WITH HIGHEST RUTTING IN F-15 LANE
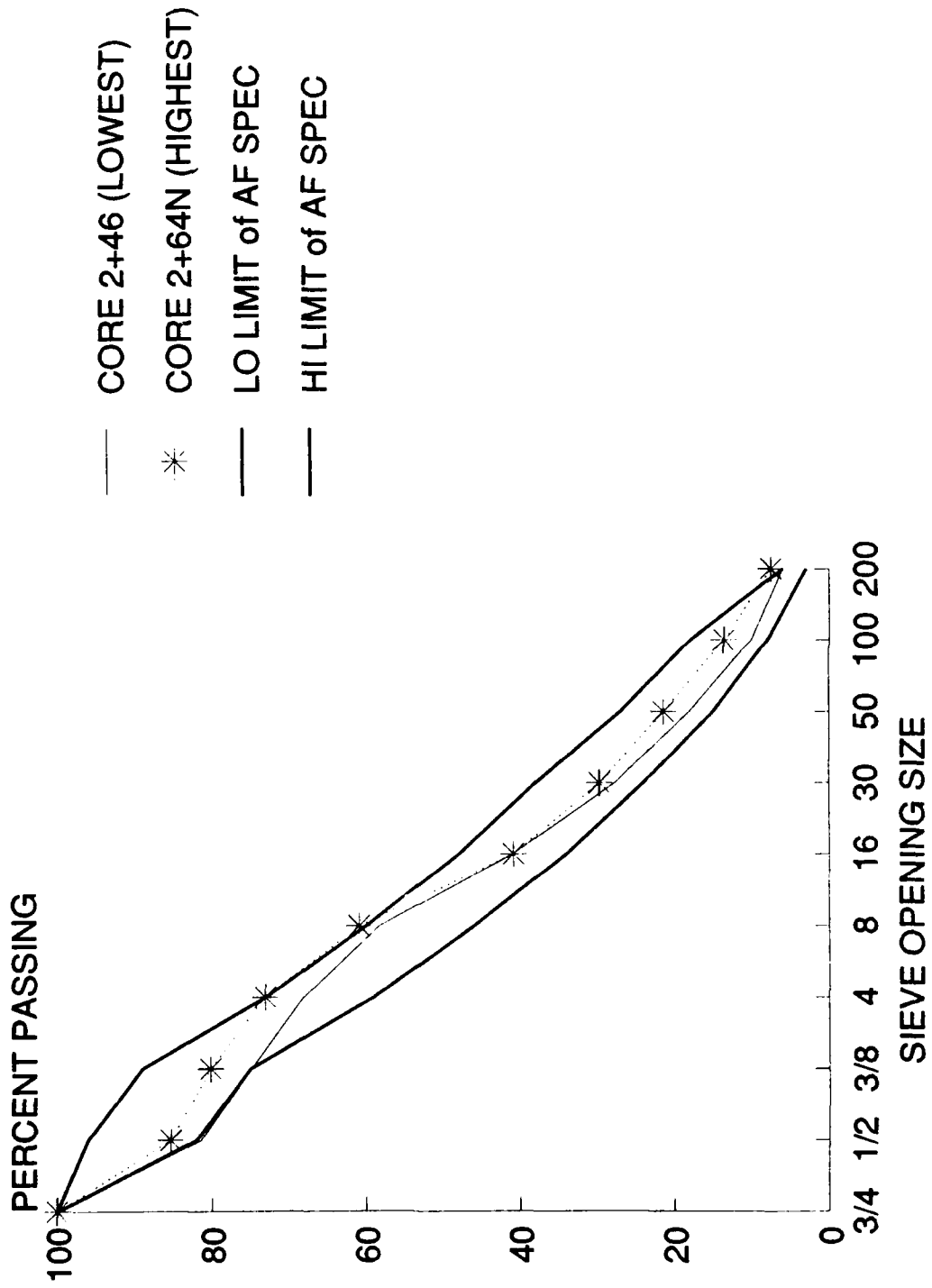
FIGURE 15. GSD OF STAS WITH LOWEST & HIGHEST RUT IN F-4 LANE
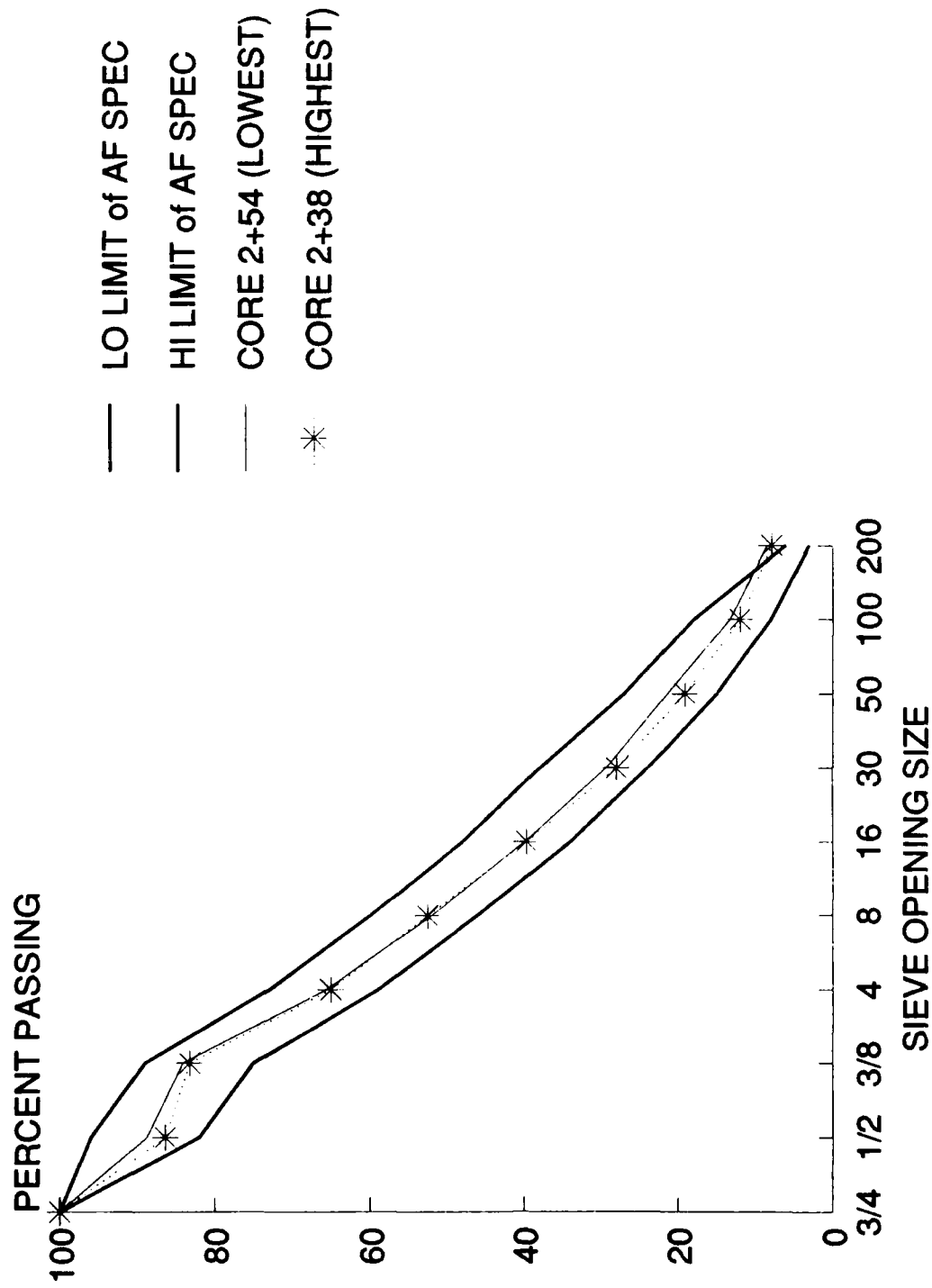
FIGURE 16. GSD OF STA WITH LOWEST & HIGHEST RUT IN F-15 LANE

VI. ANALYSIS of TEST RESULTS

The Rutting Mechanism

The high initial and relatively high final air voids in the asphalt concrete mixture indicated that the rutting experienced in both test strips was predominantly due to densification of the mix. However, there were other causes. Abrasion contributed a small amount to the rutting. This was evidenced by aggregate protruding as much as 0.25 inch from the rut floors of both test strips. Furthermore, the rut cross-sections (Appendices B1-B4) showed upheavals on both sides of the rut in both test strips, signifying that some plastic flow probably occurred.

Development of Plastic Flow

Some plastic flow mode of failure occurred in this test although air voids were well above 3 percent. The mean air voids of cores taken from the F-4 and F-15 ruts after 6000 passes were 5.78 and 4.08 percent, respectively (Table 2). This may be characteristic of rutting behavior of lean mixes under heavy loads and high tire inflation pressures. It was also thought that perhaps low confining stresses could explain this plastic behavior under high voids conditions. Carpenter and Freeman (1) showed that

loss of bond at the interface between an asphalt surface layer and the underlying concrete pavement is inherent in the system and produces a decrease in the horizontal principal stress (confining pressure) in the asphalt layer. This results in an increase in the shear stress state, which accelerates the development of plastic flow. Since the Tyndall test was conducted with asphalt overlying Portland cement concrete, the low confining pressure at the bottom of the overlay could have allowed plastic flow to occur, even with high air voids. As the material at the interface moved outward, it shoved the adjacent material upward, possibly causing it to loosen slightly. The cores extracted from the mat all appeared to have some adhesion to the underlying concrete; all but two broke loose cleanly from the substrate.

Dominant Mode of Rutting

Consideration was given to determining how much of the rut was attributable to densification of the mix and how much was due to plastic flow. The amount of densification could have been determined from the change in volume of the cores taken from the mat, provided the cores were taken near enough to the rutted area. Unfortunately, no cores were taken near the rut before application of traffic. After completion of all trafficking, two-foot offset cores were taken from the mat. If these cores ever represented the initial conditions of the rutted material,

they did not after traffic, because of the influence of
the loadcart wheels. Furthermore, the 5-foot offset cores
taken from the mat were thought to be too far from the rut
to be representative of the material trafficked. Without
reliable pre-traffic mat thickness or air voids, the
volume change due to traffic simply could not be used with
any confidence to estimate the amount of densification.

Table 2 shows the ratio of R1 to R2 after 6000 passes
as scaled from the profilograph charts. By assuming all
of R1 to be densification, a larger fraction of the total
rut in both strips was attributable to densification than
plastic flow (Figure 4). The mean ratios showed 84 percent
of the F-4 rut and 88 percent of the F-15 rut to be densi-
fication. The percent of total rut (R2) that was densifi-
cation (R1) was based on assumptions which were not exactly
true but which seemed reasonable for this test.

Traffic Effect

Computation of Pass-to-Coverage Ratio

It has been reported that the ruts of both aircraft
in the Tyndall experiment were twice the width of the
contact areas of the respective aircraft load wheels. The
traffic paths on an operating airfield are not so
channelized, but the number of passes required to apply one
application (coverage) of maximum stress on the target ($\bar{x}$),
the wheel path, can be estimated. The lateral distribution
of traffic for the main gear of a specific aircraft is

assumed to be normally distributed, centered on the target
wheel path and have a standard deviation (s) of 18 inches.
This means that the wheel path wander will fall within a
6-foot wide strip straddling the target path ($\bar{x}$) 95 percent
of the time. A second assumption is that the maximum vert-
ical stress is equal to the tire inflation pressure and is
uniform over the contact area between tire and pavement.

The probability of the target path ($\bar{x}$) getting a
coverage with one pass of the aircraft is largest when the
centerline of the loadwheel is restricted to an interval
that straddles the rut and measures plus or minus a
distance (x) of half the footprint width. The F-15 had a
footprint width of 7.75 inches under the conditions of the
Tyndall test. When x is half the footprint width, $\bar{x}$ is 0
and s is 18 inches, $z = x - \bar{x} / s = ((3.875)-0)/18 = 0.215$
for the F-15. The probability of a coverage with one pass
would then be 0.1625 and the number of passes required to
get one coverage would be the inverse or 5.9 or about 6
passes of the aircraft. Similarly, for the F-4, which had
a footprint width of 9.5 inches, z was 0.236 and the
probability of a coverage with one pass would be 0.1866 and
5.4 passes would be required to get one coverage. The
higher coverage-to-pass ratio of the F-4 is attributable to
a wider footprint. Others such as Brown and Thompson have
used a 75 percent confidence interval instead of 95 percent
for wander which led to a pass to coverage ratio of 8 (11).

Influence of Loadcart Wheels on Rut Measurement

There is sufficient reason to believe that the influence of either loadcart wheel could have affected the reported rut depths and densities in the F-15 test strip.

After laying out and marking off the F-15 test strip for traffic, the load wheel was relocated about 4 inches south to avoid tracking material deposited by the paver at the center of the auger that was suspected of being segregated. However, the trafficking layout was not relocated, resulting in the asymmetrical situation shown in Figure 17. Since the layout for the profilograph reference points were measured off the intended rut centerline, they failed to symmetrically straddle the new rut. This in effect made the north 2-foot offset actually 28 inches and allowed the loadcart drive wheel to occasionally apply load to the north reference point of the profilograph, subjecting that location to downward movement. This depression is apparent in the cross-sections developed from profilographs and levels (Appendices B2 and B4). Possibly because of the proximity of the drive wheel, at 3 stations in the F-15 test strip the densities of the now 28-inch offset cores exceeded those of the 5 foot offset cores.

More importantly, the south profilograph reference point, which should have been 2 feet offset from the rut

54
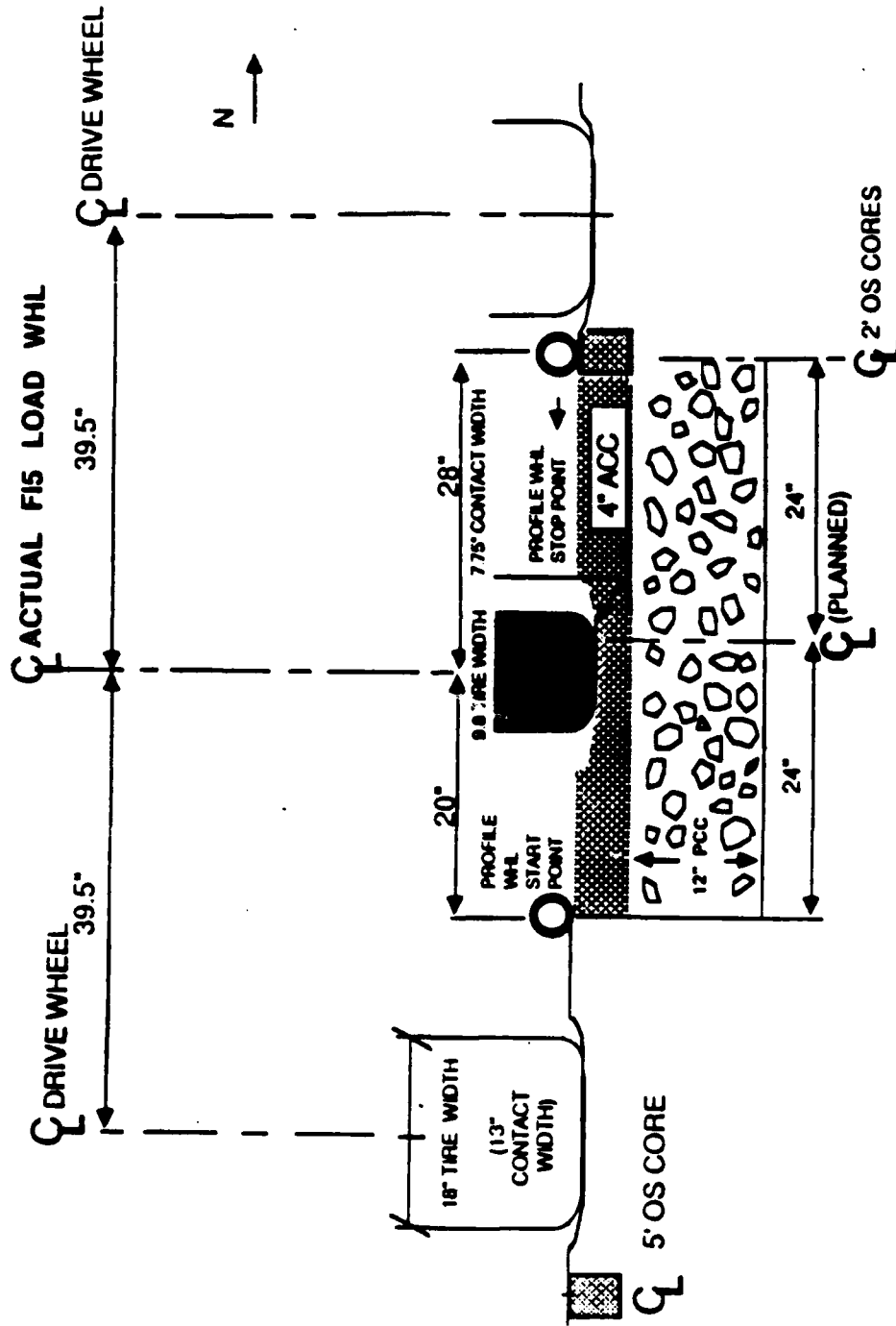
FIGURE 17.   CROSS-SECTION AT STATION 2+38 SHOWING OFFSET OF F-15 CENTERLINE

was actually only 20 inches from the load wheel. Mean density of the cores taken 5 feet off the rut exceeded that of the 2 feet offset cores by about 1 percent in both test strips (Table 2). This implied that the 2-feet offset cores may have been within the plastic flow zone of influence of the load wheel, producing a slight decrease in densities due to upheaval of the mix. When the offset distance was reduced from 24 inches to 20 inches, the influence of the loadcart wheel was increased dramatically.

The COE had reported that rutted asphalt mixes have been known to undergo increases in VTM with time during periods of non-traffic (12). The implication was that a form of stress relief had allowed the rut to recover from some of its deformation. To determine if such recovery occurred for the Tyndall sections, a rod and level survey was performed 11 months after completion of trafficking to retrace the centerline of rut protile elevations for both test strips. The survey produced the same centerline profiles as the final test survey, conducted 11 months earlier. Neither of the above surveys nor the profilographs were congruent with the original survey that was conducted before any traffic was applied. Since the original level survey appeared to be unreliable, the amount of vertical movement experienced by the profilograph reference points and the resulting effect on rut measurement reported could not be determined.

Mix Quality Effect

Density Effect

Cores extracted from the mats of both test strips were heated and recompacted using the 75 blow per face Marshall criteria. When these were compared to the 5-foot offset cores from the mat it was learned that both test strips had been compacted during construction to about 100 percent of their recompacted core densities. On the average, the recompacted density and TMD of the mix from the F-4 test strip were significantly lower than the F-15 test strip at the 95 percent confidence level. Similarly, the average recompacted VTM and VMA of the mix from the F-4 test strip were higher (Table 2). The VTM of the F-15 test strip mix were highly variable, as indicated by the coefficient of variation (CV) in Table 2.

Although both recompacted and mat densities between the test strips were significantly different at the 5 percent level, their ratios (relative compaction) were not. The within-the-rut percent compactions after traffic were not significantly different between strips either. The average percent compaction found from the cores taken from the rut, for each of the test strips, was 102.3 percent for the F-4 and 102.2 percent for the F-15. Even so, partly because of the mix leanness, the mean VTM found from the cores taken from the rut of the F-4 strip was still 5.78 percent, 2 percent above the 4 percent target of

the JMF. For the F-15 strip, the mean VTM of the rutted cores was 4.08 percent. Air voids did not drop into the 2-3 percent range, so as to invite dominant plastic flow.

Asphalt Deficiency Effect

The leanness of the mix contributed to high VTM and VMA values in the recompacted Marshall specimens and in the pavement (Table 2). Figures 18 and 19 show the reduction of air voids with increasing binder content for the 5 foot offset (untrafficked) cores in the F-4 and F-15 test strips, respectively. The 17 stations tested fell between 5 and 10 percent air voids. The VTM values would have been even higher but for the excessive -200 material in the mix. The data from the mix design are also shown in the figures. The mix design and field data fit reasonably well on opposite ends of a common curve. Since the mean mat densities were equal to the recompacted densities, data in these Figures 18 and 19 support the reasonableness of using recompacted cores to estimate initial mix design density.

Figures 20 and 21 show that the variation of percent material passing the number 200 sieve found in the untrafficked cores also explain much of the variation of VTM, since the -200 and binder content curves show similiar trends. The almost inverse relationship between binder content plus -200 material and air voids was to be expected since both parameters reduce air voids.

58
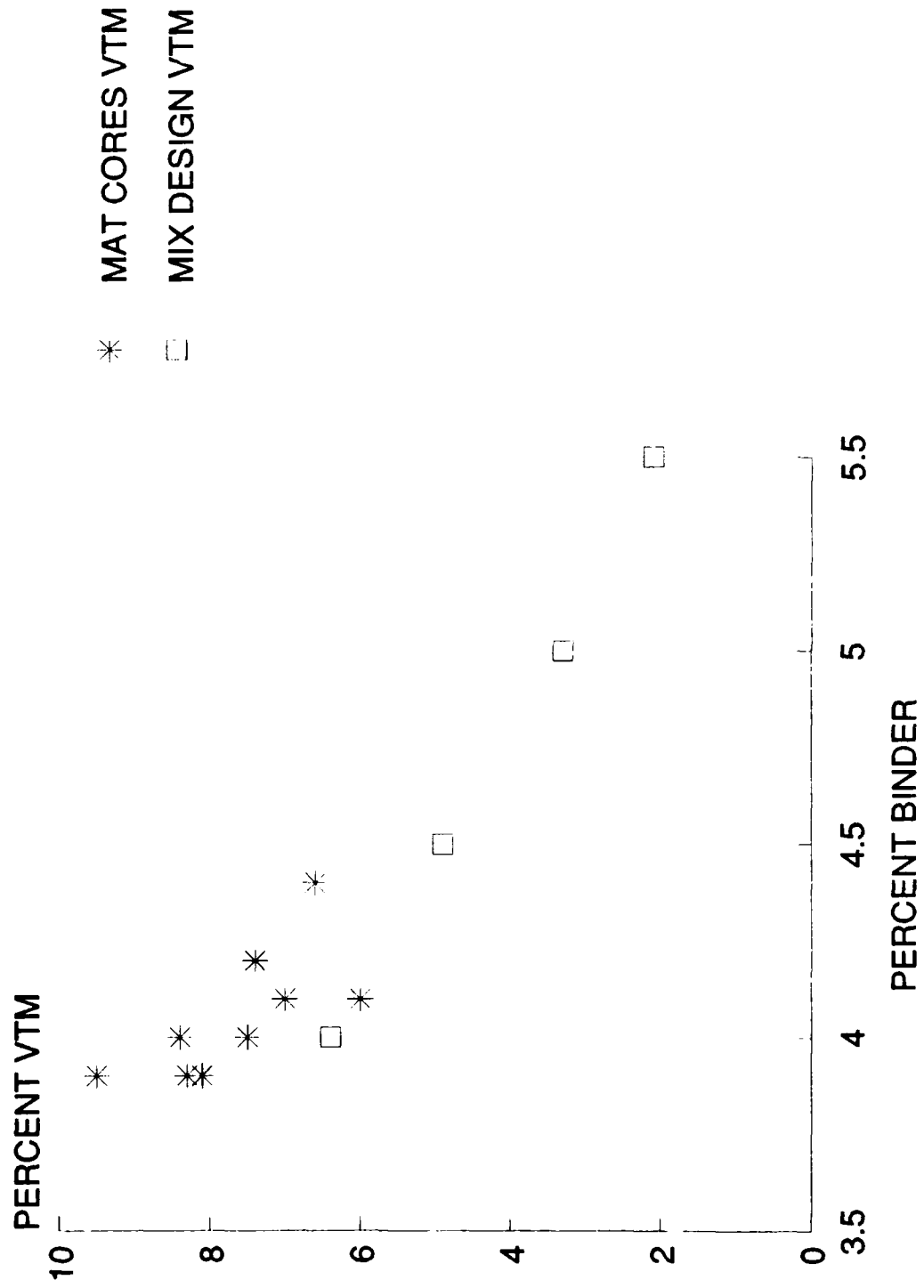
FIGURE 18. F-4 LANE % AC EFFECT ON INITIAL & MIX DESIGN VTM
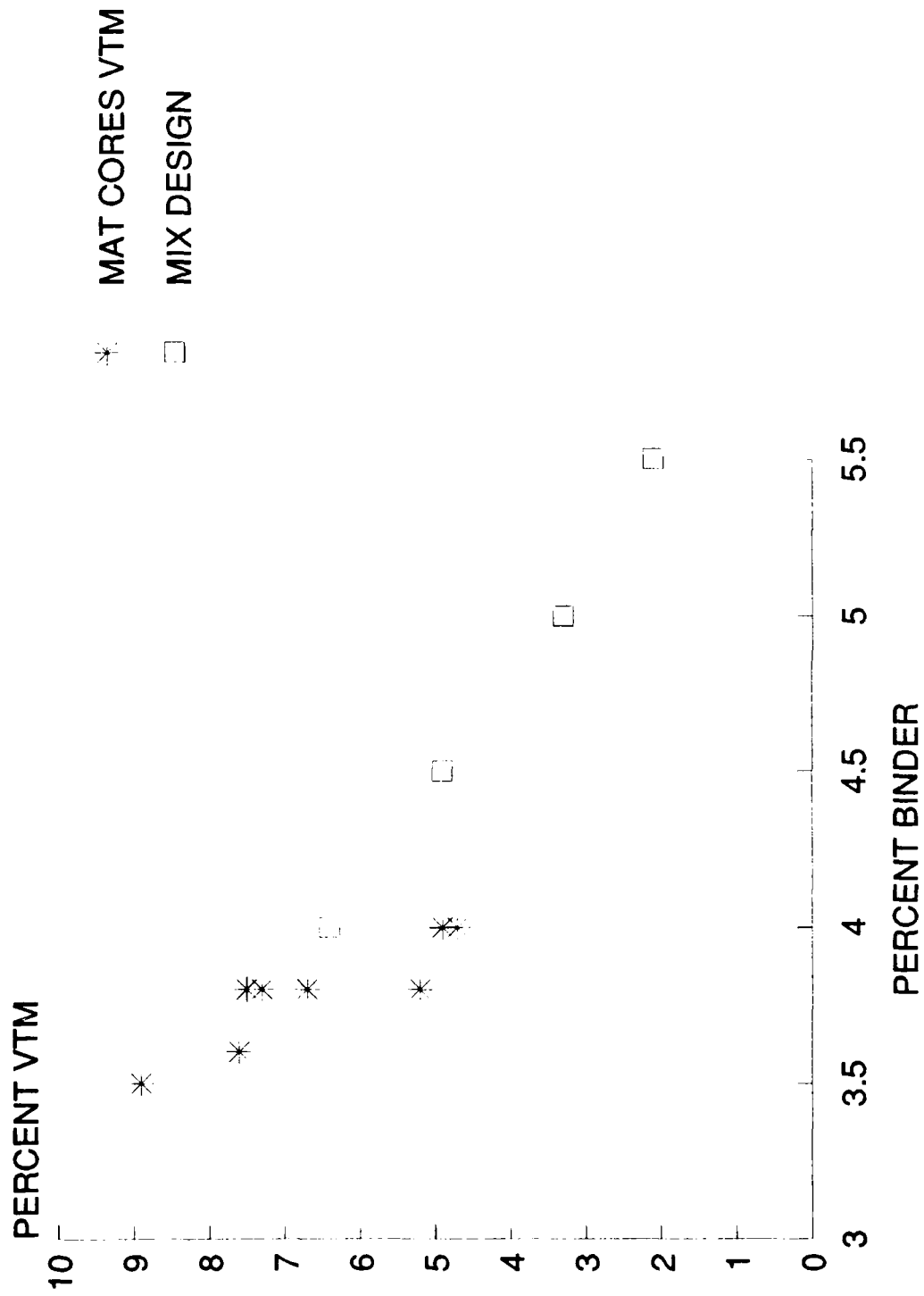
FIGURE 19. F-15 LANE % AC EFFECT ON INITIAL & MIX DESIGN VTM

60
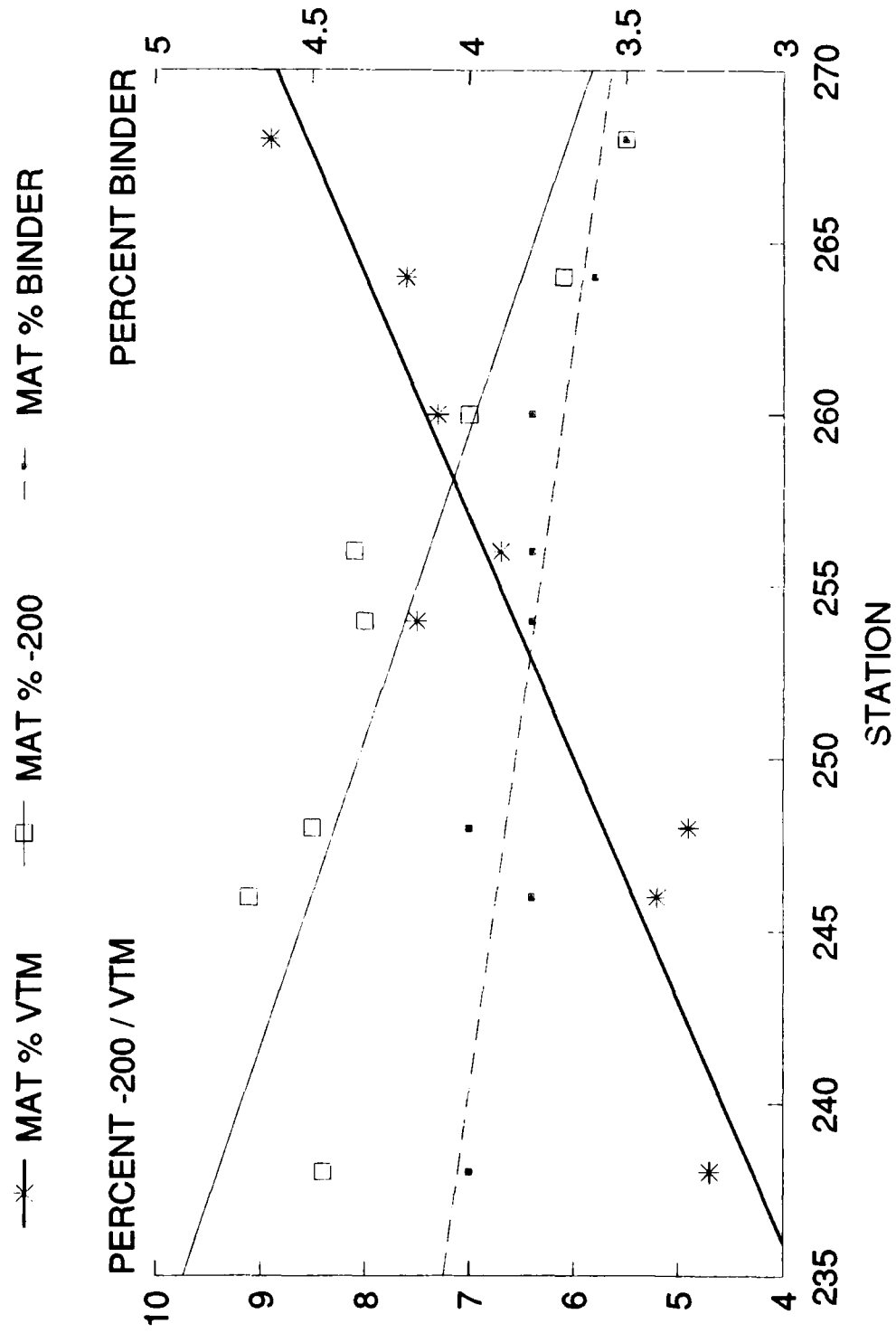
FIGURE 20. F-15 LANE % AC AND -#200 EFFECT ON INITL MAT VTM
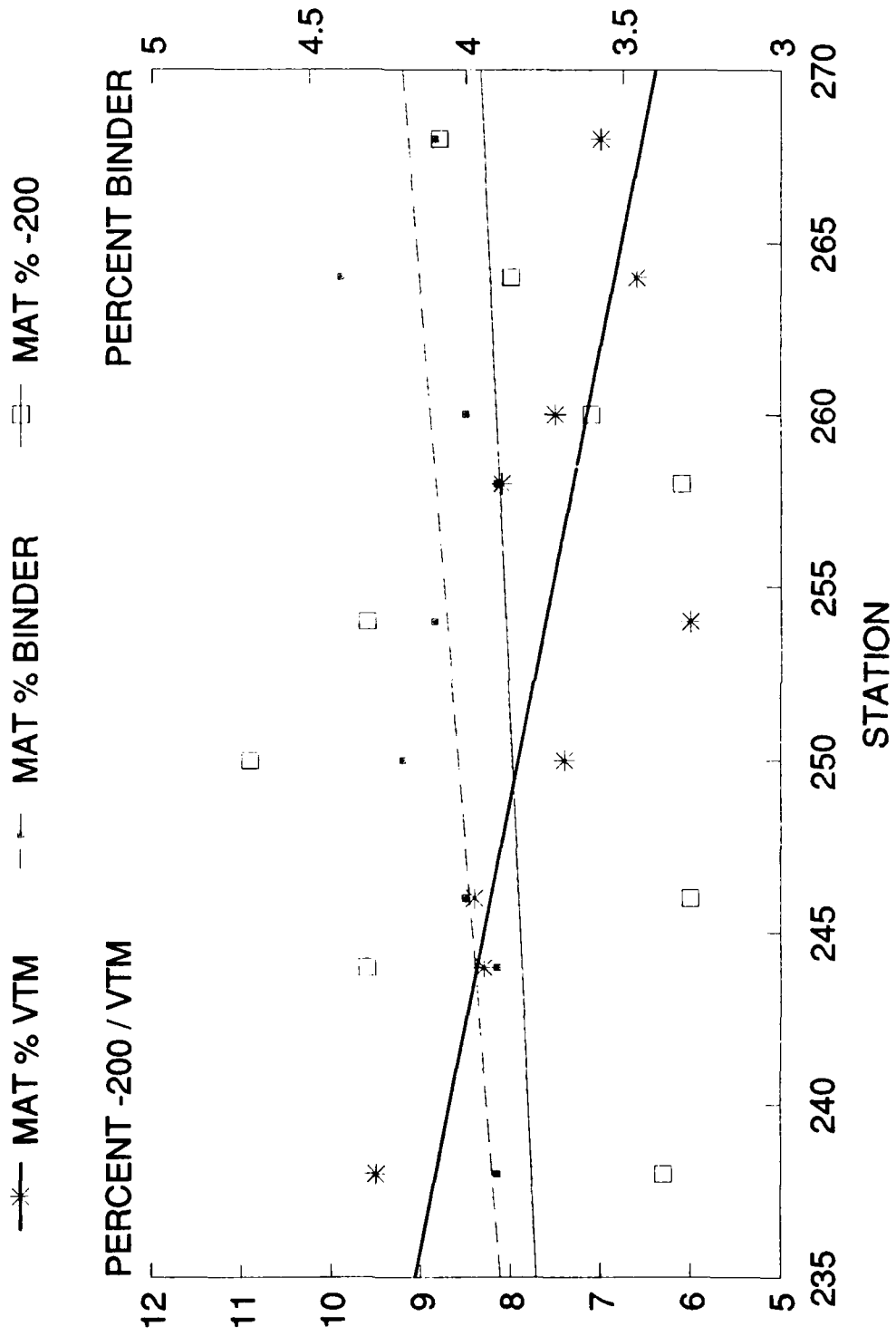
FIGURE 21. F-4 LANE % AC AND -#200 EFFECT ON INITIAL MAT VTM

Only 4 of the 17 stations sampled had been compacted to a VTM as low as 3.5 percent after traffic was completed (Table 2). These stations were all in the F-15 test strip and notably all of them represented the least rutting in that strip. The average percent of laboratory recompaction for these F-15 stations that experienced the lowest rutting was 103 percent, after traffic. The significance of these observations was not determined since pre-traffic samples were not taken from the locations that represented the rut.

Ordinarily, a leaner mix will be more resistant to rutting since there is less asphalt to lubricate the aggregate, provided greater compactive effort is employed to assure that it is constructed near optimum density. The leanness of this mix, with the compactive effort specified, contributed to high VTM and VMA values in the Marshall specimens, in the untrafficked cores and even in the heavily trafficked cores from the ruts. It is not known if the total rutting of this mix was less or more than it would have been at optimum binder content. The densification was certainly more, but the plastic flow was probably less than would have occurred at optimum binder content. This particular mix might experience durability problems if placed in long-term service on an airfield because of the high air voids and low binder content.

Cause of Deficient Asphalt Content

The lean mix produced in the test appeared to be attributable to faulty procedures used to extract binder from the plant output which was reportedly used to calibrate the plant asphalt scales. Appendix C2 data for the core extractions showed that a substantial fraction of the -200 material passed through the filter of the centrifuge. When the extract was run through a second high-speed centrifuge, a mean of 1.2 percent by weight of mix of these fines was recovered. Extractions of the plant product evidently employed only the first centrifuge, overlooking the loss of fines, and apparently surmised that all weight lost in the extraction was binder, thereby over-estimating binder content by 1.2 percent (by weight of mix) on the average. The CV of the mix binder content for the two strips were 3 and 4 percent, respectively.

Gradation Effect

Minus 200

Air Force criteria limits -200 content for airfields to a range from 3 to 6 percent. Figures 15 and 16 showed that both test strips were placed with excessive -200 material. In fact, excess -200 material was found in every one of the cores from both test strips. This could be due to the incorrect extraction procedure used since the fines in the extract were incorrectly identified to be asphalt. Or the excess in -200 material could have been simply due

to inaccurate assessment of the stockpile gradation. Both possibilities called for addition of -200 material to the mixture. Excess -200 material has been said to increase rutting of bituminous pavements (9) in the presence of excessively low VMAs or rich mixes and in some circumstances, to reduce it. However, despite excessive minus 200 material in both test strips, it is notable that the average VMAs were not extremely low (10) and the mixtures were lean. Therefore, the test results from this study do not indicate that excessive -200 content contributed to the rutting or instability of the test strips. In any case, there was no significant difference in -200 content between the test strips (Table 2).

Minus 8

Figures 15 and 16 showed that although the F-15 test strip contained an uniformly-graded mixture, the F-4 strip mixture was hump-graded. This is probably the reason that the recompacted density and TMD of the mix from the F-15 test strip were significantly higher than from the F-4 test strip (Table 2). Similarly, the average recompacted VTM and VMA of the mix from the F-4 test strip were higher. All of the above is in spite of the fact that the F-4 test strip had significantly higher binder content (Table 2). It is also interesting to note from Table 2 that there was significantly more aggregate passing the number 8 sieve in

the mix from the F-4 test strip. The F-4 strip contained a larger percentage of fine aggregate than the F-15 strip, yet had higher VMA. It appeared that the amount of -8 aggregate was an important discriminating measure of compaction potential between test strips.

Temperature Effect

Because traffic was not applied until early fall, the pavement temperatures (Figure 3 and Appendix A3) recorded in this experiment were not, on the average, as high as summer temperatures commonly reported for airfields located in the southern USA. These relatively moderate temperatures caused an average pavement surface temperature of 102^0F for the period during which the 6000 passes were applied, resulting in a lower total rut depth than would probably have occurred at peak summer temperatures.

Comparison of the Test Strips

Rut Measurement

The F-15 test strip rutted significantly faster than did the F-4; on the average, it took 5,000 passes of the F-4 to cause a 0.4-inch rut depth but only 1,000 passes of the F-15.

The coefficient of variation of the F-15 test strip rut measurement was twice that of the F-4 strip (Table 2). The effect of traffic on rut depth measured at some

observation stations in the F-15 strip was sometimes twice that of other stations. These non-uniform responses were sometimes large and sometimes occurred within intervals of only a few feet. This variable within-test-strip perform- ance of the mixture under the F-15 aircraft load indicated that significant mix variation occurred between observation stations. However, as indicated by the higher coefficients of variation, the only core mix properties that appeared to be variable within the F-15 test strip were the air voids and the aggregate gradation (Table 2).

One possible contributing factor to the larger variability detected in the F-15 rut measurement (Figure 9) was the tracking of the loadcart drive wheel on the profilograph reference points. More likely, the variabil- ity of the F-15 strip rut was because of more frequent change of loadcart operators in that test strip.

Mix Characteristics

Analysis of the mix physical properties showed a number of significant differences between the two test strips. The F-4 cores were not as uniformly graded and resulted in lower densities when recompacted than did the F-15 cores. The F-test (Table 2) showed, with 95 percent confidence, that the recompacted densities of the two test strips were from different populations. This was evident since the computed absolute value of the F-test was larger

than the test value (Fo) at a 5 percent significance level. The t-test proved, with 95 percent confidence, that the recompacted density of the F-15 was significantly higher than that of the F-4.

Based on the t-test (Table 2), at a 5 percent significance level, the initial mat densities, as indicated by the 5 feet offset cores, were significantly higher in the F-15 test strip; while initial mat VMA, AC, and FA were significantly higher in the F-4 strip. It can be hypothesized that every one of those differences probably reduced the differential rutting between the two test strips. In other words, it is likely, but can not be proven that if there had been no differences between the mixes, an even higher rutting differential would have been observed. The differences in measured rut depths showed up shortly after start of traffic and continued to increase throughout the application of traffic.

Application of Test Results

Taxiway rutting was the focus of this study. Unlike runways, unacceptable rut depths for taxiways are normally a function of how much the pavement structure can tolerate and not how much aircraft can tolerate. Unacceptable rut depth in this study had been arbitrarily set at one inch, but most taxiways can function with rutting of this magnitude. The mean rut depth experienced in the Tyndall test after 6,000 passes (5,700 coverages) of the

F-15 was just over 0.7 inch. If a typical installation flew 140 F-15 sorties daily, and 20 percent of those sorties were with the C/D model, it is estimated that 3,696 passes divided by 6 passes per coverage = 616 coverages during the six months of hot weather could take 9 years to accumulate a rut of 0.7 inch. This estimation ignores the rutting effect of cool weather traffic, lighter F-15s, and other aircraft whose main gear wheels might track the same wheel path. Since 9 years is about the average life of flexible overlays on airfields anyway, the rutting experienced in the Tyndall test implies that airfield pavements may be adequate for the F-15C/D aircraft. However, in several ways which have been explained, those test pavements were not typical of airfield pavements; nor were temperatures representative of summer conditions in the southern United States. This meant that application of the results from the fall, 86 test to other installations will be more limited than was desired.

VII. CONCLUSIONS and RECOMMENDATIONS

The Threat

In the Tyndall test, it was learned that it takes
5,000 passes of the F-4 to produce a 0.4-inch rut depth,
but only 1,000 passes of the F-15. These numbers cannot be
applied to all mixtures as they were derived from only one
particular mix. Furthermore, the comparison of 5 times as
much F-4 traffic as F-15 cannot be extrapolated to failure
for this mix since 0.4-inch is far from failure of the
layer and only the densification mode of rutting was
dominant in this test. Had trafficking been continued to
failure, the rutting of these sections probably would have
included more plastic flow, with unknown relative effects
between test strips. However, in a qualitative manner, the
Tyndall test established that the F-15 will rut bituminous
pavements with fewer applications of traffic than will the
F-4.

Possible Remedies

Another experiment conducted during the summer months
would probably be expected to show more rutting for both
the F-4 and F-15 test strips than was experienced in this
study. If additional rutting occurs due to the higher

loading, the Air Force installations that operate the heavyweight F-15 will probably need to replace flexible taxiway pavements much more often than in the past. If frequent repairs on these taxiways interfere with the operational mission of the airbase, the engineer may need to consider stiffer materials than conventional asphalt mixtures or reduce binder content and specify higher compaction from the contractor. Either way, the extra expense could be more cost-effective if quantities were kept to a minimum. For flexible overlays of concrete pavements, this might be accomplished with an inlay type of mill-and-replace method similar to that used for barrier cable impact pads where only damaged areas are repaired. The remedy will not be so simple for conventional flexible pavements where rutting may not be confined to the asphaltic layers.

More Testing Required

When a mix is constructed with less asphalt than the job mix formula (JMF) requires, higher compactive efforts must be employed in the construction of the mat to achieve the desired density. The density achieved during construction of the Tyndall test strips was about equal to recompacted densities using the Marshall compaction effort, but somewhat less than that of the JMF, largely because of insufficient asphalt. The resulting high air voids

permitted much more densification than would have occurred
had the mix been constructed with the correct amount of
asphalt. At optimum asphalt content air voids would have
been lower, but this might have permitted more plastic
flow. So, one may not conclude that this mix would rut
more or less had the asphalt content been equal to that of
the JMF.

Because of the relatively moderate pavement tracking
temperatures, the measured rutting of pavements during the
Tyndall test was probably lower than would have been
experienced during the summer.

The differential rutting between test strips may have
been more if the mixtures had been the same. This can be
hypothesized from the significant differences in such
characteristics as initial mat density, asphalt content,
percent fine aggregate, VMA, and recompacted core density.
In other words, if there had been no differences in the
mixes of the two test strips, a higher rutting differential
probably would have been observed.

Consequently, another experiment will be necessary to
properly assess the potential rutting effect of the F-15 on
standard airfield pavements.

Test Improved Mixtures

Cores extracted from the mats of both test strips
were recompacted using the 75 blow per face Marshall

criteria, which is the density usually anticipated in the mat after 2 or 3 years of traffic. It was learned from the 5-foot offset cores that on the average, both test strips had been compacted during construction to about 100 percent of their recompacted core densities. The military standard calls for 98 to 100 percent to insure a waterproof, durable surface that will not consolidate appreciably under traffic. Although the 5-foot offset cores from both test strips were found to have initial mat densities equal to 100 percent of their respective recompacted densities, both strips continued to densify under traffic, up to about 102 percent of their recompacted densities. To minimize densification under traffic, the laboratory compaction effort should be based on a close approximation of the anticipated traffic compaction. This particular mix should have been constructed to at least 98 percent of the F-15C/D trafficked density or 101 percent of the recompacted (Marshall) density. Additional laboratory densification can occur only by increasing the laboratory compactive effort; however, the standard 75-blow Marshall effort on recompacted specimens broke many points of contact off the parent rock in all of the recompacted cores examined. An increased laboratory effort, using the Marshall apparatus would undoubtedly be even more destructive. An alternative compaction method appears to be needed. The Corps of Engineer's Gyratory Testing Machine (ASTM D3387) has been

used since the early 1960s to achieve higher compactive efforts without cracking the aggregate (2) and could have an application here. However, the compactive effort that would be required to consistently achieve 98-100 percent of this higher density (i.e. of the F-15C/D trafficked density) in the field, may be quite difficult to obtain and result in more costly construction procedures.

It is recommended that standard pavements be incorporated as control sections in part of an experiment to determine if a change in the mix or density requirement could possibly improve performance. The new sections should include binder content at Marshall optimum and at gyratory optimum. The latter would reduce the amount of binder from that of conventional design but may make highly compacted sections feasible. Two levels of load should again be applied simultaneously.

Test Conventional Structures

The Tyndall test did not compare performance of the two aircraft on conventional flexible pavements. By confining the test to flexible overlays of concrete pavements, uniformity of support was assured. However, in a conventional flexible pavement, the rutting would not have been confined to the asphaltic layer. The rutting would have been distributed among the base course, subbase course and subgrade as well and may have been more or less

severe. Since most airfield taxiways are of this type of construction, it is necessary that future experimentation investigate conventional flexible pavements as well as overlays of concrete.

Apply the Lessons Learned

The next experiment should apply several lessons that were learned from the fall, 86 test:

1. The mix should be produced in a modern, calibrated, "on-line" plant with an experienced operator so that the gradation can be controlled. Adjust the JMF for manufacture of -200 material, if such is evident.

2. Use only trained or experienced technicians for lab and field quality control and measurements. Establish an accurate grid of vertical elevation and horizontal control points before applying any traffic.

3. Due to non-uniformity of asphalt concrete, take cores that are intended to represent initial conditions from as close to the observation station and rut as possible and take them before applying the traffic.

4. Do not introduce rutting variation by off-setting the tracking centerline. Instead, center the rut cross-section measurements symmetrically on the centerline. The

profilographs can be more easily interpreted if the straight-edge is leveled before recordiny the profile.

5. Rutting failure may arbitrarily be defined as one inch of permanent deformation but traffic need not be stopped at this point. It would be better to apply traffic until moderate cracking or other signs of impending safety hazard to the loadcart operation is evident to glean maximum information from the test. If possible, traffic should be applied until the rut in the F-4 test strip has reached the defined failure depth.

6. Apply traffic during periods when pavement temperatures are highest (Summer).

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APPENDICES

APPENDIX A

TEST MEASUREMENTS

APPENDIX A1. RUT DEPTHS OBSERVED with TRAFFIC in F-4 TEST STRIP

(File: F4R1FUL)
(STA 2+62 WAS USED FOR STA 2+64 AS LATTER'S DATA WAS MISSING)

PASSES	OBSERVATION STATION										
(100s)	238	244	246	250	254	258	260	262	268	AVG	SE
0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000
3	.12	.15	.13	.14	.13	.12	.15	.13	.10	.13	.005
6	.19	.22	.20	.24	.26	.25	.22	.22	.20	.22	.007
9	.23	.29	.23	.28	.30	.30	.28	.26	.21	.26	.011
12	.28	.30	.30	.32	.33	.25	.30	.28	.26	.29	.008
14	.29	.33	.30	.34	.36	.34	.25	.31	.29	.31	.011
17	.29	.34	.29	.34	.36	.33	.35	.32	.29	.32	.009
20	.31	.37	.31	.35	.37	.35	.34	.31	.28	.33	.010
26	.30	.34	.32	.37	.38	.36	.34	.35	.31	.34	.009
29	.32	.35	.31	.36	.39	.36	.35	.36	.29	.34	.010
32	.33	.32	.31	.36	.37	.35	.36	.33	.31	.34	.007
35	.29	.31	.34	.37	.35	.36	.35	.35	.31	.34	.008
38	.34	.37	.33	.40	.37	.37	.35	.35	.30	.35	.009
40	.34	.37	.34	.40	.40	.40	.40	.40	.35	.38	.009
43	.36	.39	.37	.40	.39	.38	.40	.39	.34	.38	.006
46	.36	.40	.34	.43	.42	.43	.43	.39	.37	.40	.011
50	.34	.39	.36	.45	.44	.44	.42	.41	.38	.40	.012
55	.37	.41	.39	.45	.45	.43	.43	.42	.36	.41	.010
60	.37	.42	.34	.49	.46	.45	.43	.42	.36	.42	.016

STANDARD ERROR of MEAN (SE) = STD DEVIATION of all 9
                                   OBSERVATIONS / SQ RT of 9 OBS

APPENDIX A2. RUT DEPTHS OBSERVED with TRAFFIC in F-15 TEST

(File: F15R1FUL.CAL)
Sta 2+62 used to replace the missing 2+64 values)

PASSES	OBSERVATION STATION									
(100s)	238	246	248	254	256	260	262	268	AVG	SE
0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3	.25	.24	.24	.12	.14	.24	.22	.24	.21	.02
6	.36	.34	.37	.21	.24	.38	.39	.34	.33	.02
9	.46	.41	.36	.24	.26	.41	.45	.39	.37	.03
12	.50	.44	.45	.27	.30	.46	.48	.49	.42	.03
14	.53	.45	.45	.30	.32	.44	.49	.50	.44	.03
17	.60	.49	.51	.30	.32	.54	.53	.52	.48	.04
20	.57	.52	.48	.32	.34	.53	.56	.53	.48	.03
26	.73	.51	.48	.33	.36	.56	.60	.57	.52	.04
29	.70	.56	.49	.31	.34	.55	.57	.54	.51	.04
32	.67	.52	.50	.35	.38	.56	.61	.60	.52	.04
35	.73	.51	.52	.37	.40	.60	.61	.65	.55	.04
38	.72	.53	.48	.40	.46	.64	.67	.68	.57	.04
40	.73	.51	.53	.40	.43	.63	.65	.69	.57	.04
43	.79	.56	.54	.40	.45	.70	.72	.69	.61	.05
46	.81	.57	.57	.45	.48	.69	.73	.71	.63	.04
50	.94	.61	.60	.48	.52	.78	.81	.76	.69	.05
55	.94	.59	.63	.52	.53	.79	.81	.76	.70	.05
60	1.02	.60	.58	.57	.60	.83	.96	.71	.73	.06

STANDARD ERROR of MEAN (SE) = STD DEVIATION of all 8
OBSERVATIONS / SQ RT of 8 OBS

APPENDIX A3. PAVEMENT SURFACE TEMPERATURES UNDER TRAFFIC
(Averaged over Time Trafficked)
(FILE: TEMP3.WK1)

ACCUMULATED #PASSES	INCREMENTAL AVG SURF TEMP UNDR TRAF	DEG*PASS	AVG SURF TEMP UNDER ACCUMULATED TRAFFIC
300	100	30000	100
600	124	67200	112
900	110	100200	111
1200	80	124200	104
1430	94	145820	102
1730	85	171320	99
2000	103	199130	100
2300	84	224330	98
2600	84	249530	96
2900	111	282830	98
3200	100	312830	98
3500	93	340730	97
3800	100	370730	98
4000	122	395130	99
4300	85	420630	98
4600	120	456630	99
5000	122	505430	101
5500	89	549930	100
6000	123	611430	102

APPENDIX B

RUT CROSS-SECTIONS

B1   F-4 TEST STRIP RUT XSECTION

by PROFILOGRAPH

SURFACE PROFILE BEFORE TRAFFIC

STATION
238

R1 0.36"
R2 0.41"

AFTER TRAFFIC

244

R1 0.39"
R2 0.48"

246

R1 0.30"
R2 0.42"

250

R1 0.43"
R2 0.51"

254

R1 0.44"
R2 0.48"

258

R1 0.40"
R2 0.50"

260

R1 0.40"
R2 0.49"

268

R1 0.86"
R2 0.42"

SCALE:
HORIZONTAL : 1" : 12"
VERTICAL : 1" :1"

APPENDIX B1. F-4 TEST STRIP RUT CROSS-SECTION
BY PROFILOGRAPH

B2 F-15 TEST STRIP RUT XSECTION

by PROFILOGRAPH

SURFACE PROFILE BEFORE TRAFFIC

STATION

238

R1 1.02"
R2 1.12"

AFTER TRAFFIC

246

R1 0.58"
R2 0.70"

248

R1 0.50"
R2 0.57"

254

R1 0.57"
R2 0.63"

256

R1 0.60"
R2 0.70"

260

R1 0.83"
R2 0.93"

268

R1 0.71"
R2 0.84"

SCALE:
VERTICAL : 1" : 1"
HORIZONTAL : 1" : 12"

**APPENDIX B.2. F-15 TEST STRIP RUT CROSS-SECTION
BY PROFILOGRAPH**

B3   F-4 STRIP RUT XSECTION

by ROD & LEVELS

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)

F-4 LANE, STATION 2+38 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
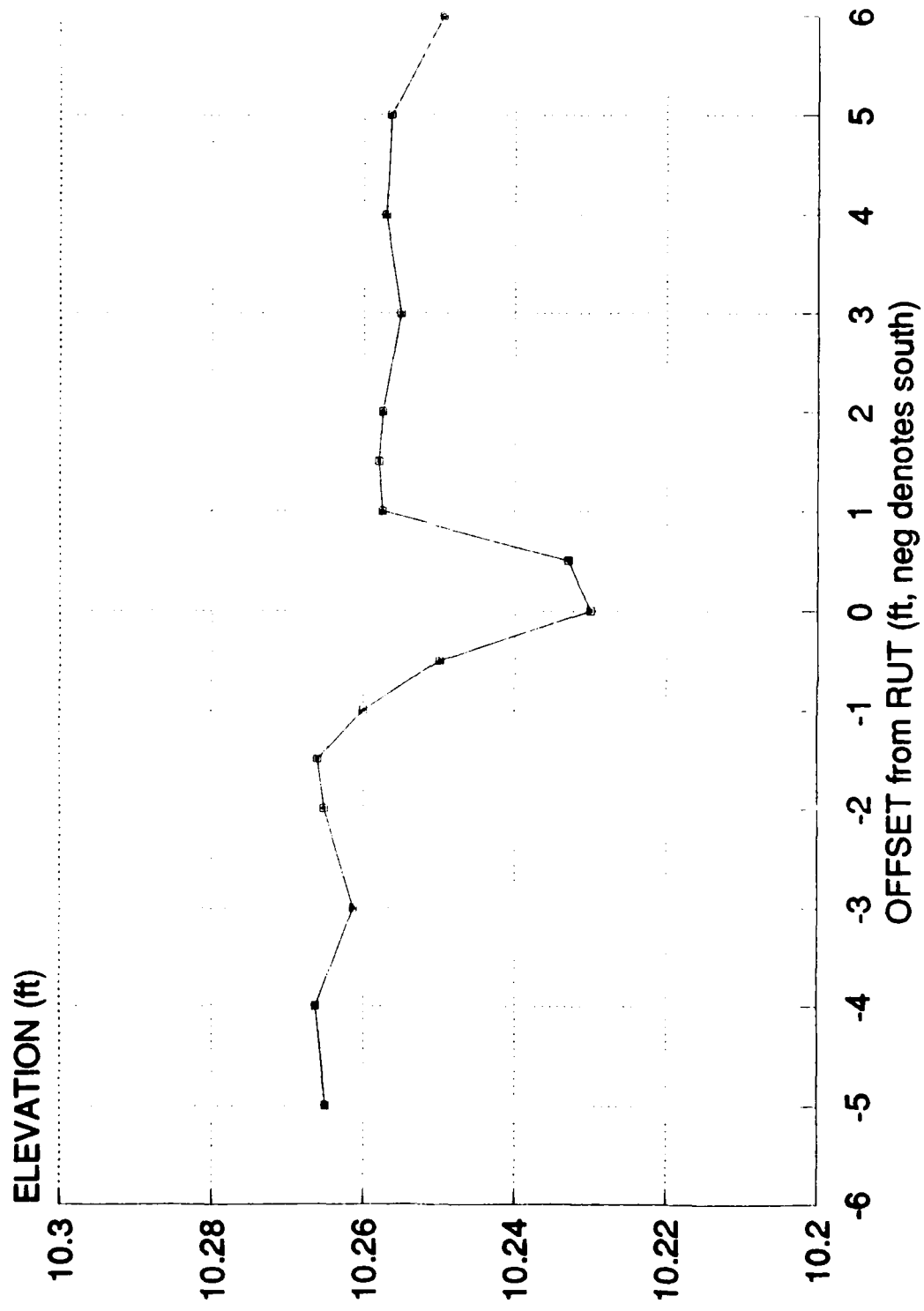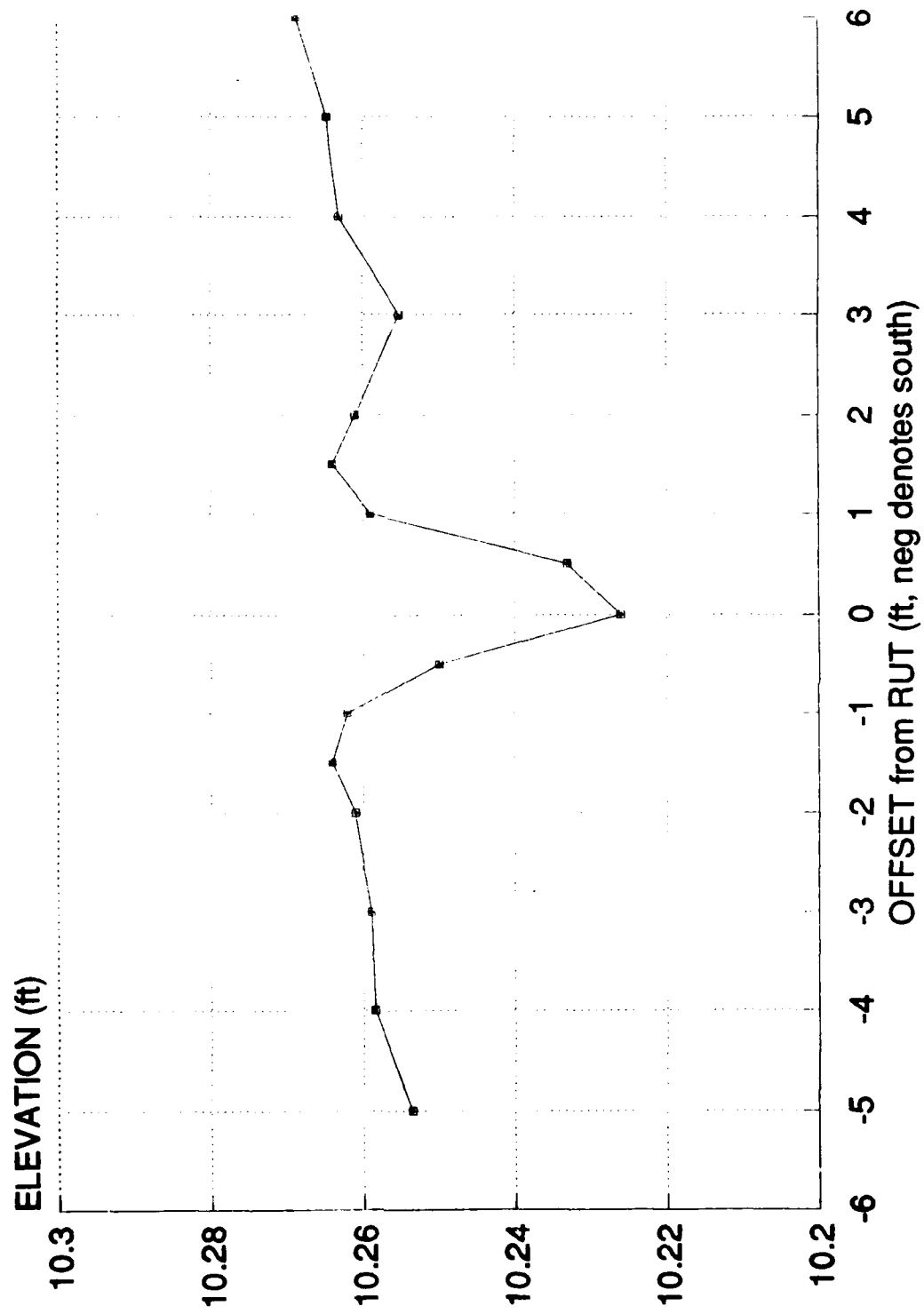
F-4 LANE, STATION 2+44 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
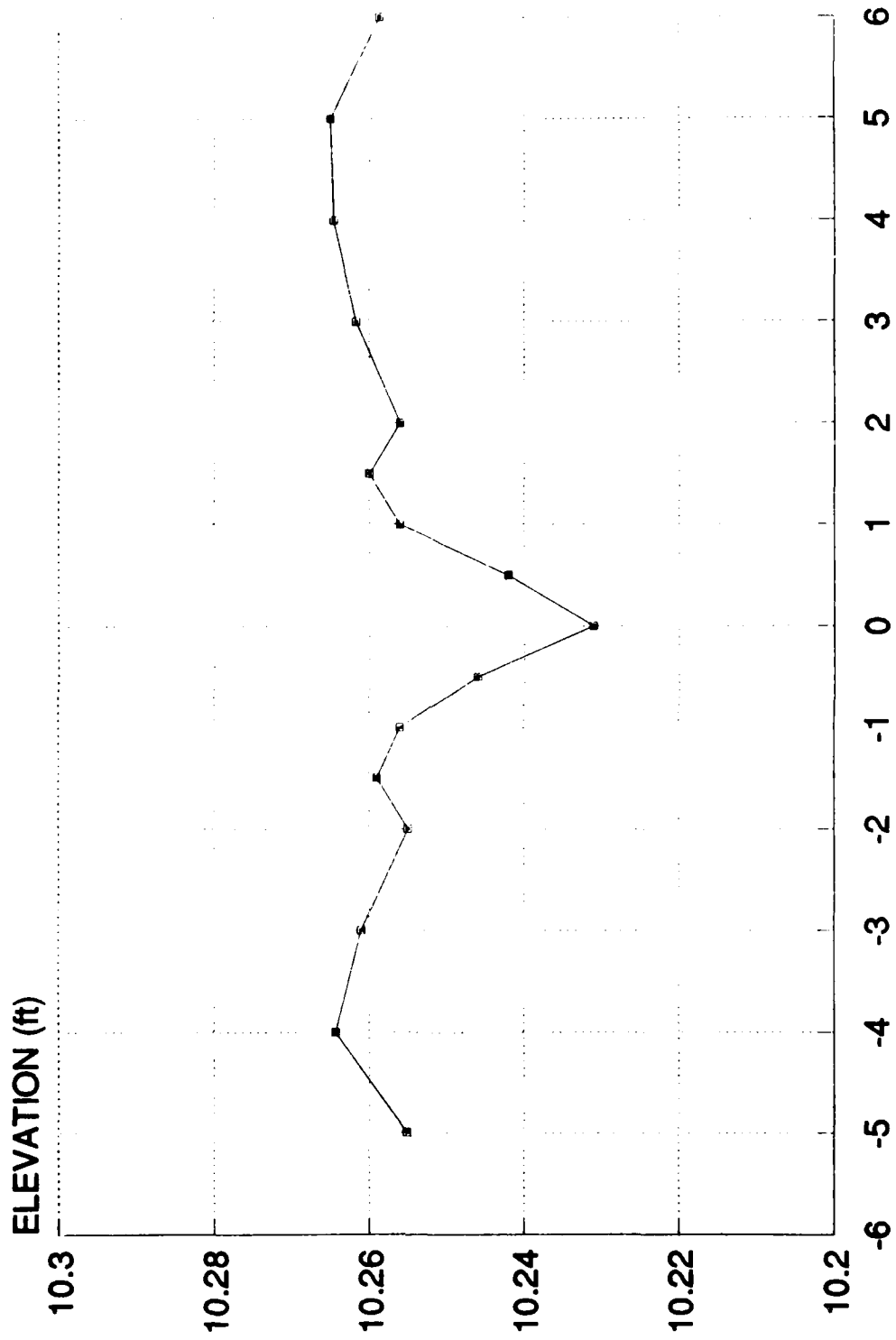
F-4 LANE, STATION 2+46 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
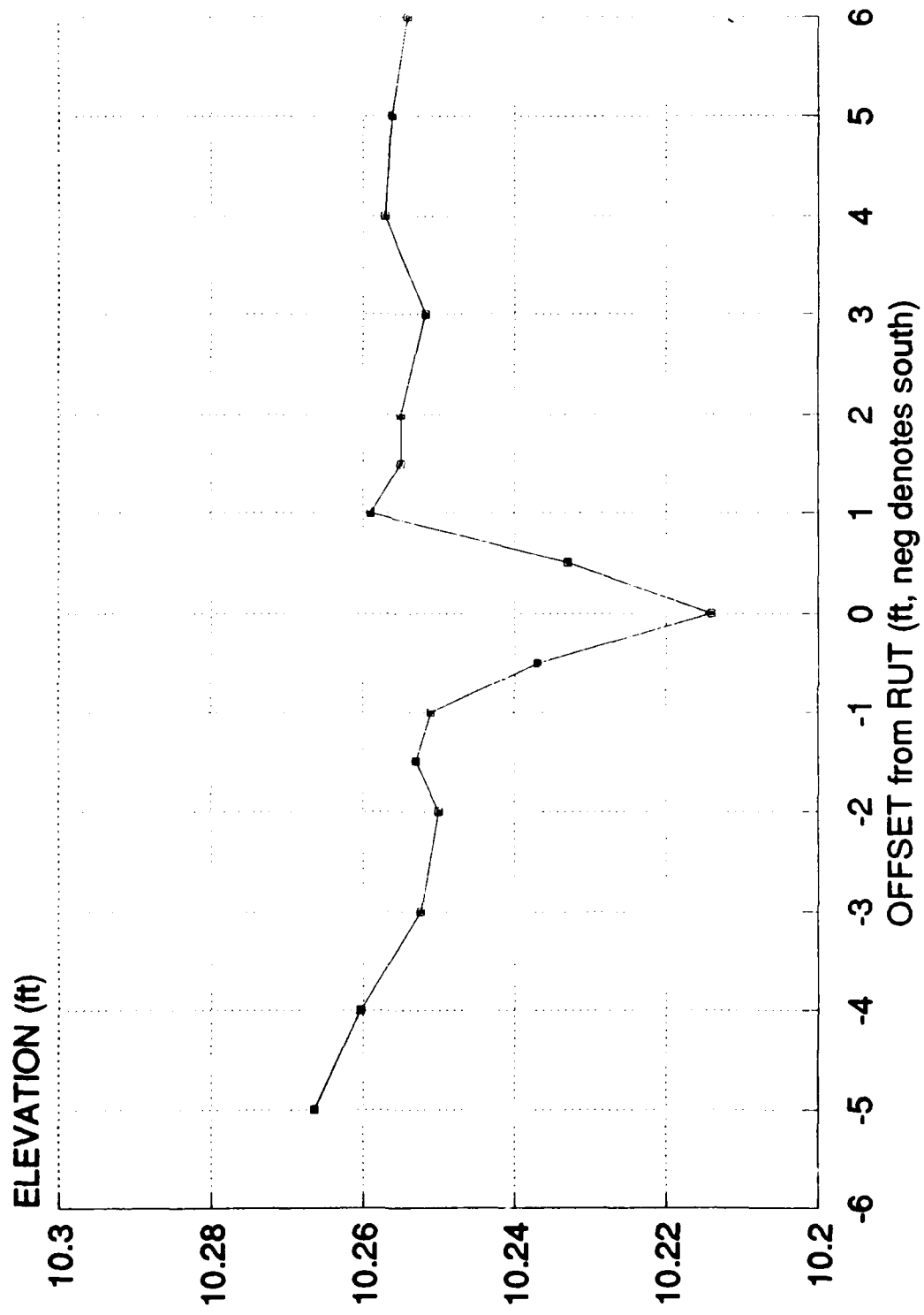
F-4 RUT, STATION 2+50 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
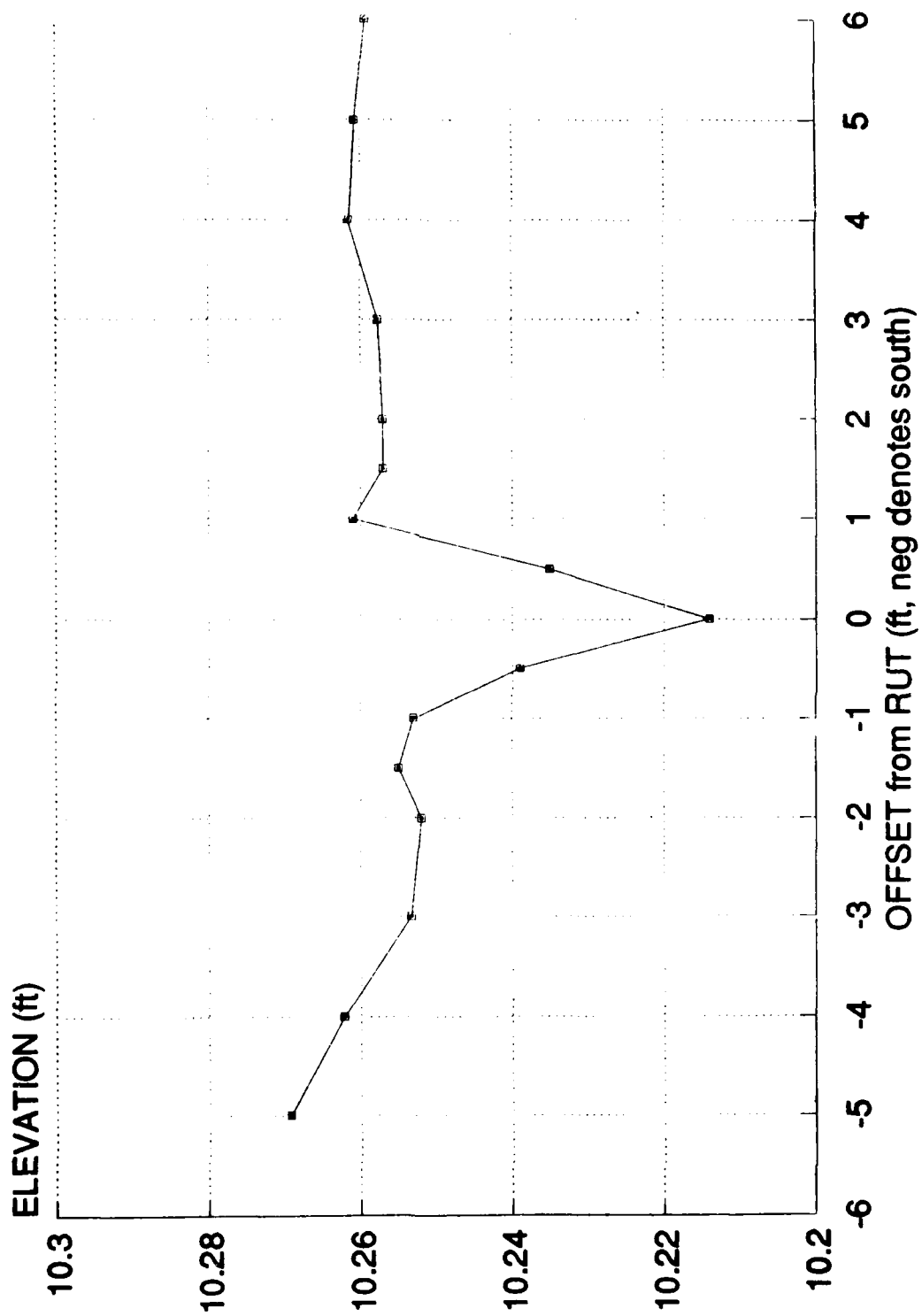
F-4 LANE, STATION 2+50A CROSS-SECTION AFTER 6000 PASSES

F-4 LANE, STATION 2+54 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
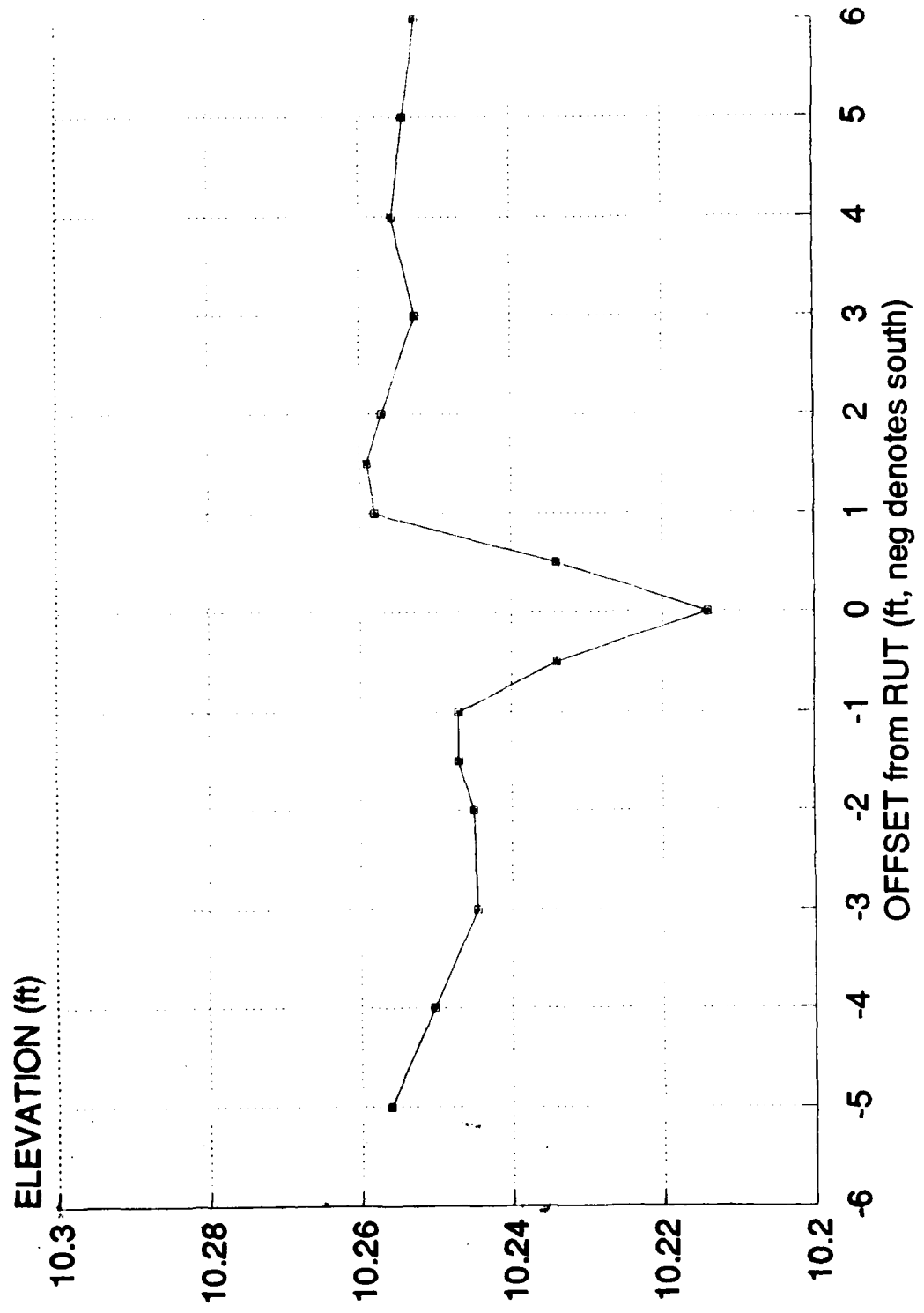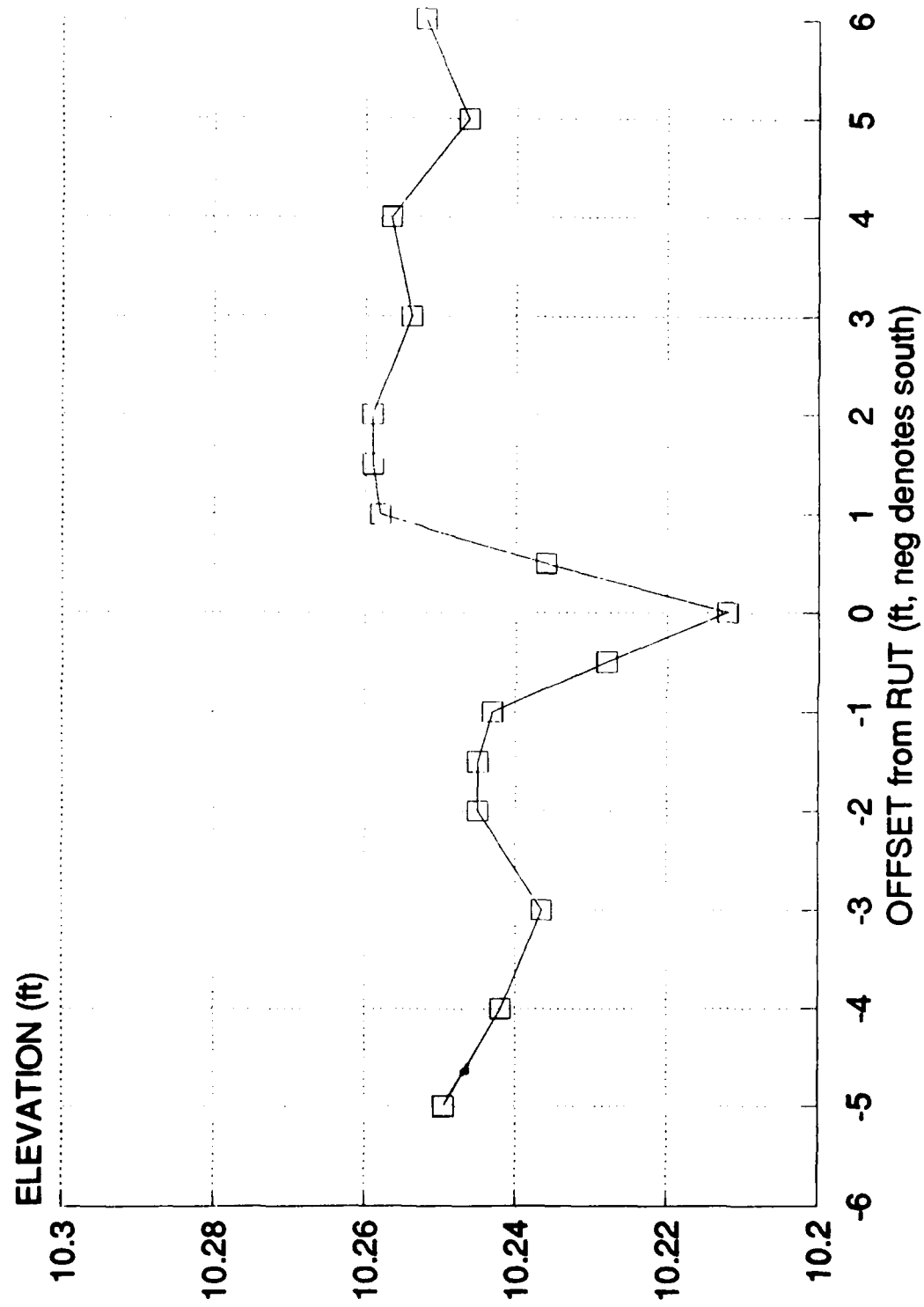
F-4 LANE, STATION 2+58A RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
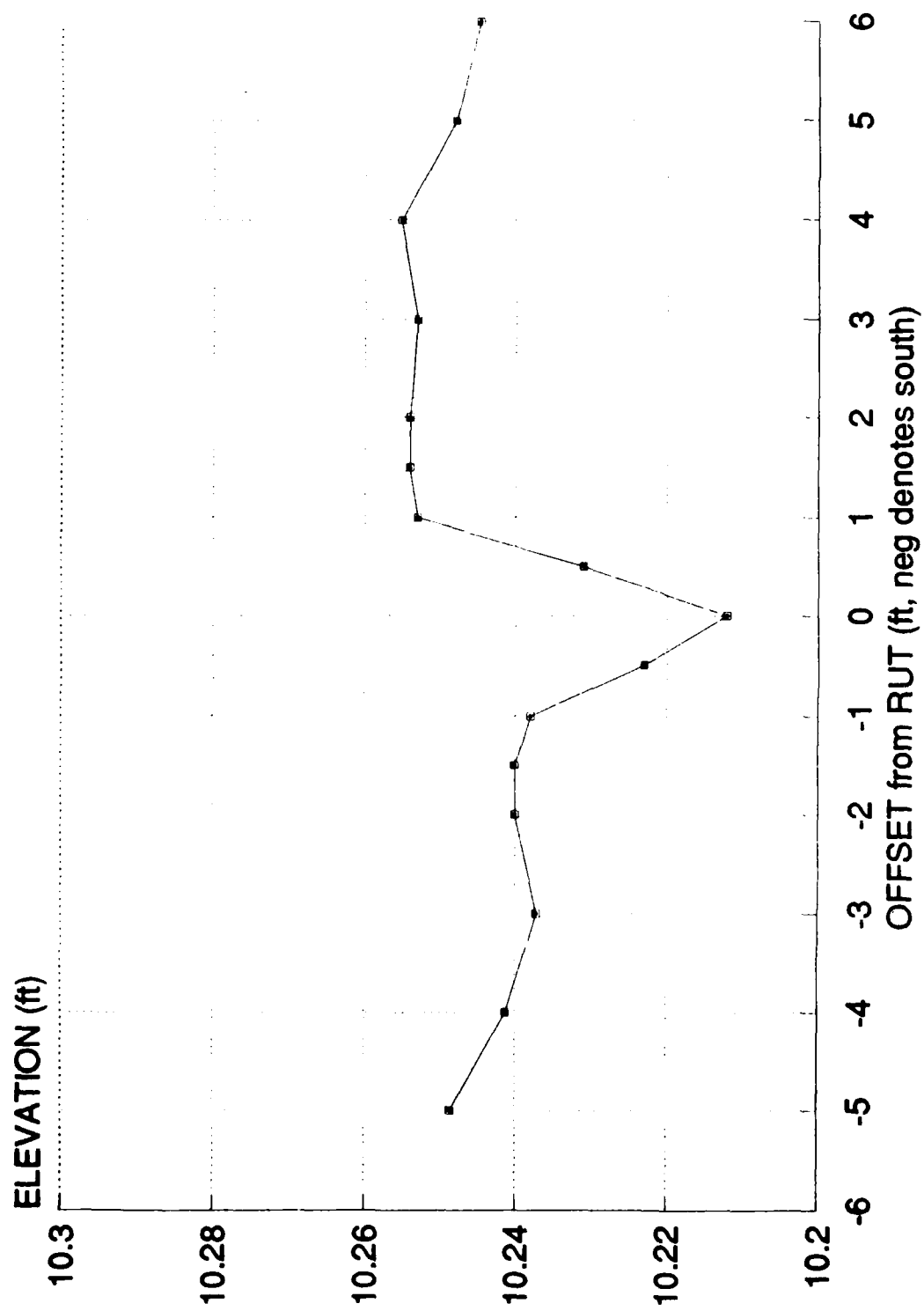
F-4 LANE, STATION 2+58 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)

F-4 LANE, STATION 2+60 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
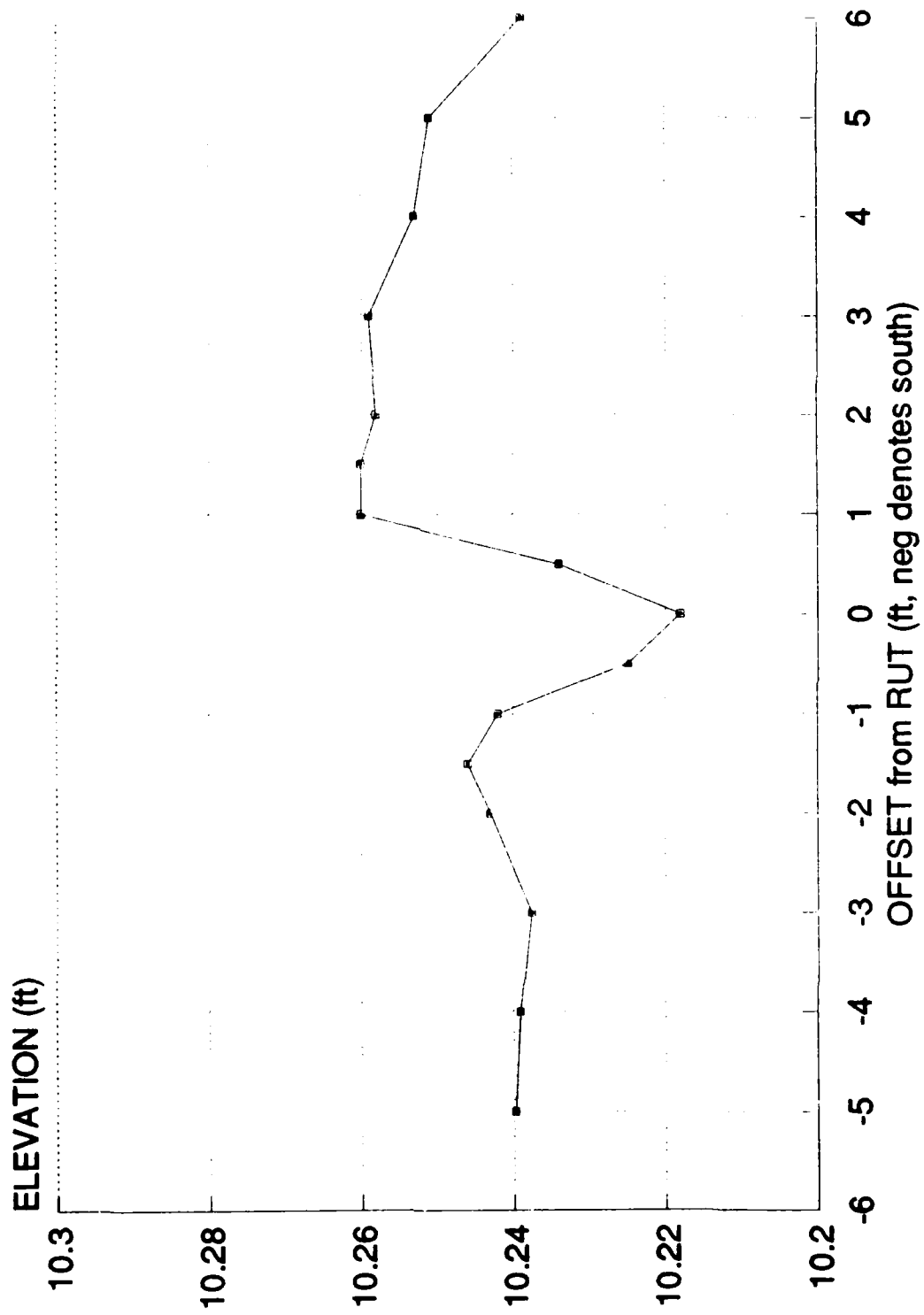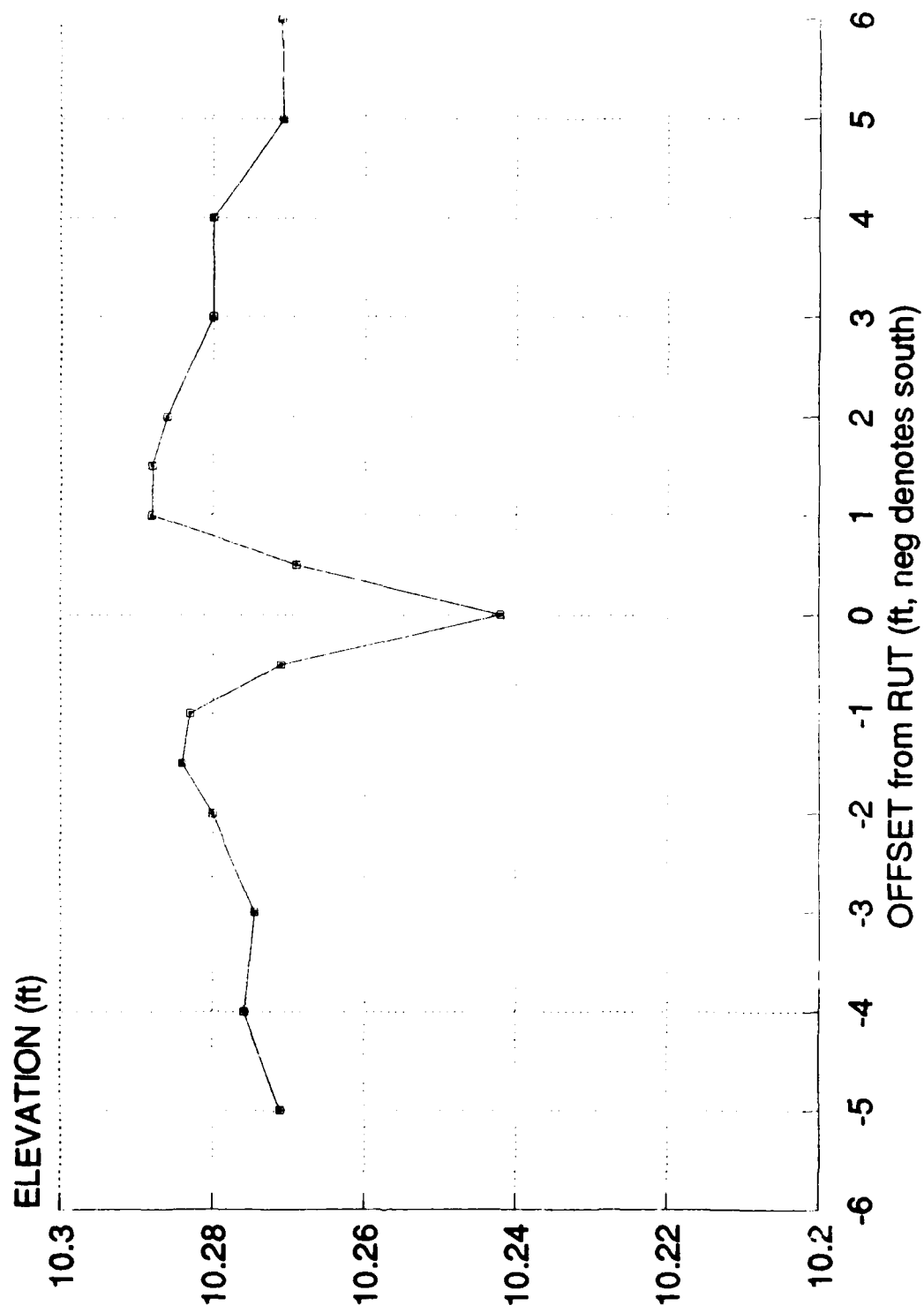
F-4 LANE, STATION 2+64 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
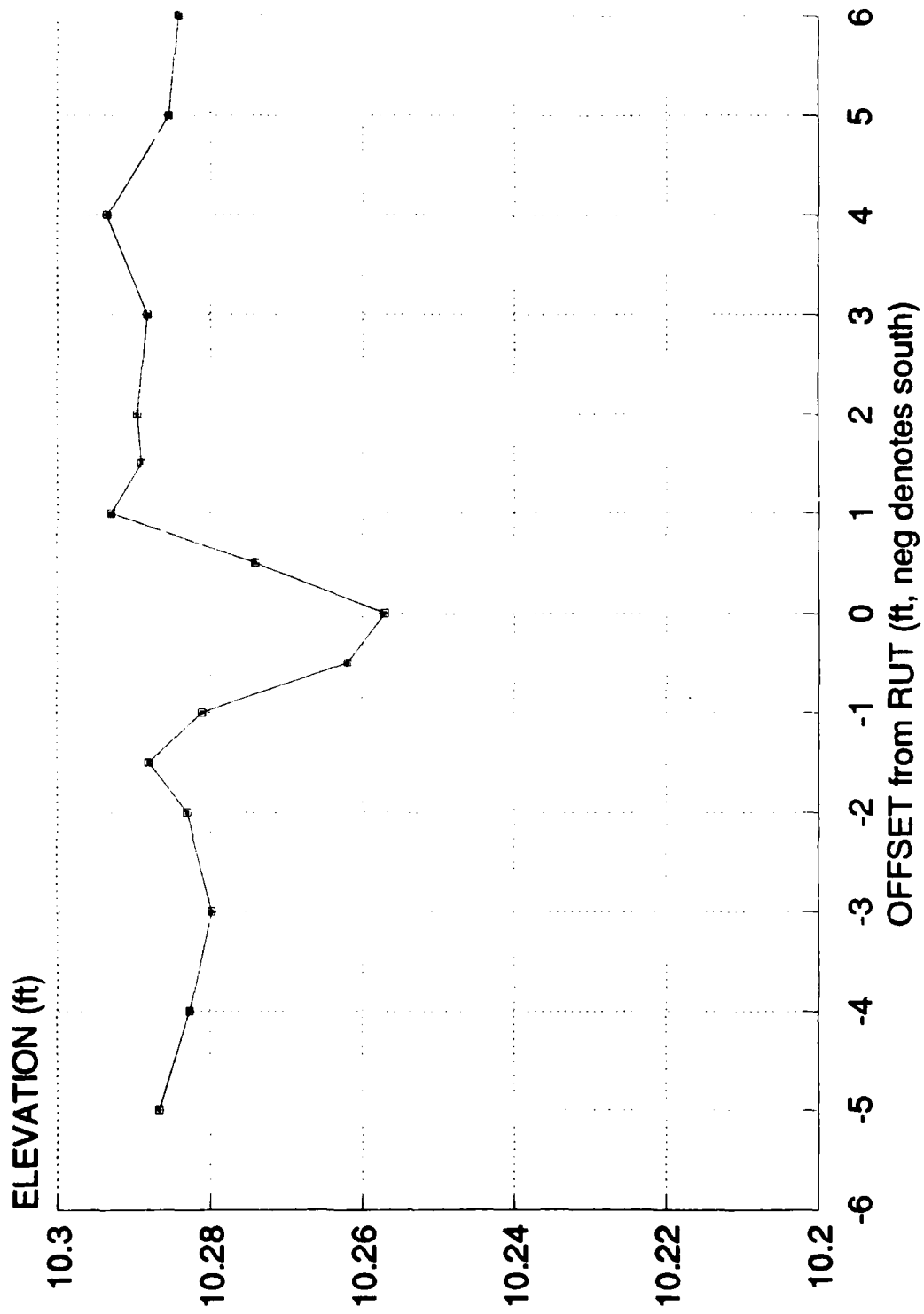
F-4 LANE, STATION 2+68 RUT CROSS-SECTION AFTER 6000 PASSES

B4 F-15 STRIP RUT XSECTION

by ROD & LEVELS

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
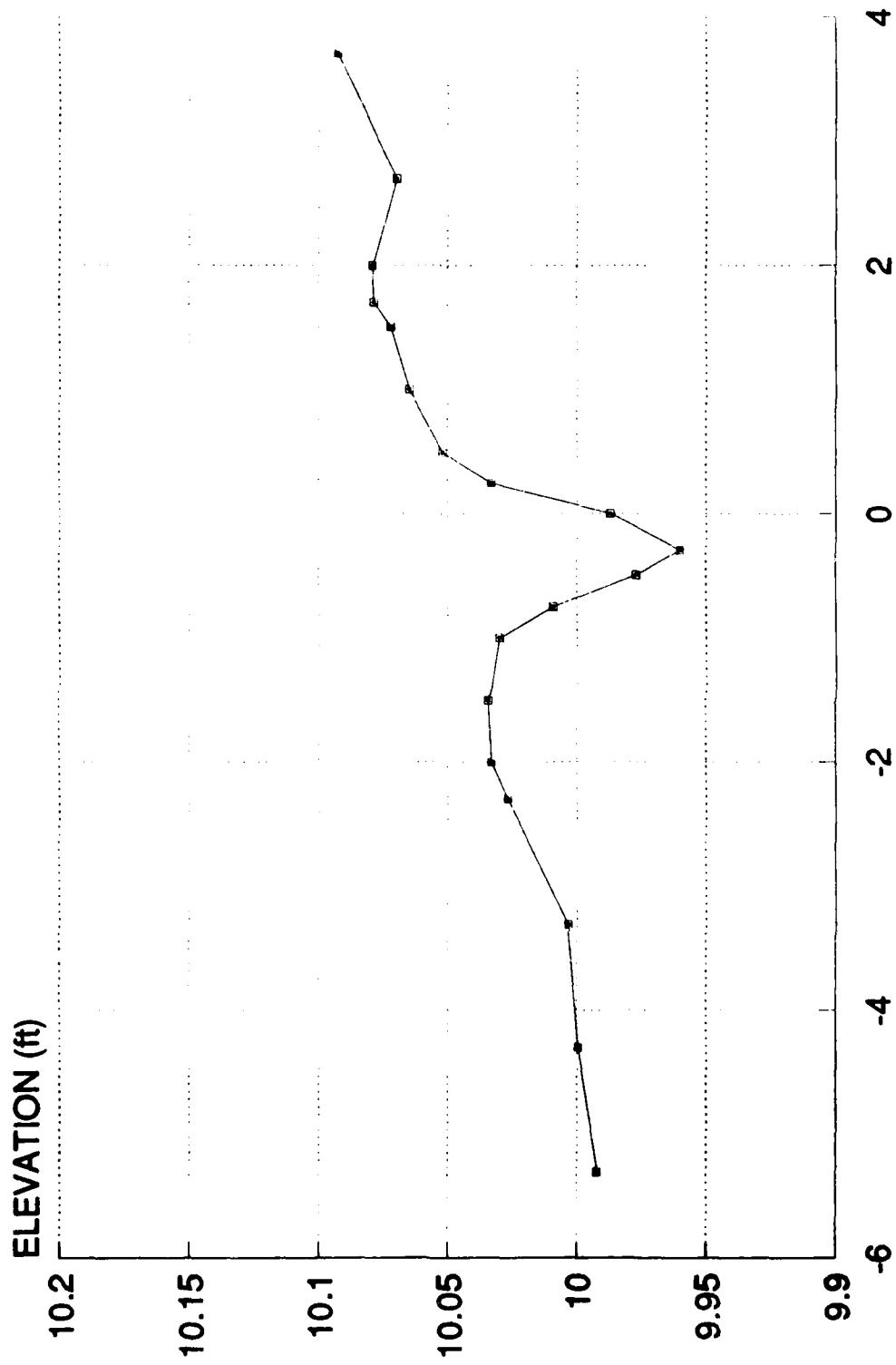
F-15 LANE, STATION 2+38 CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
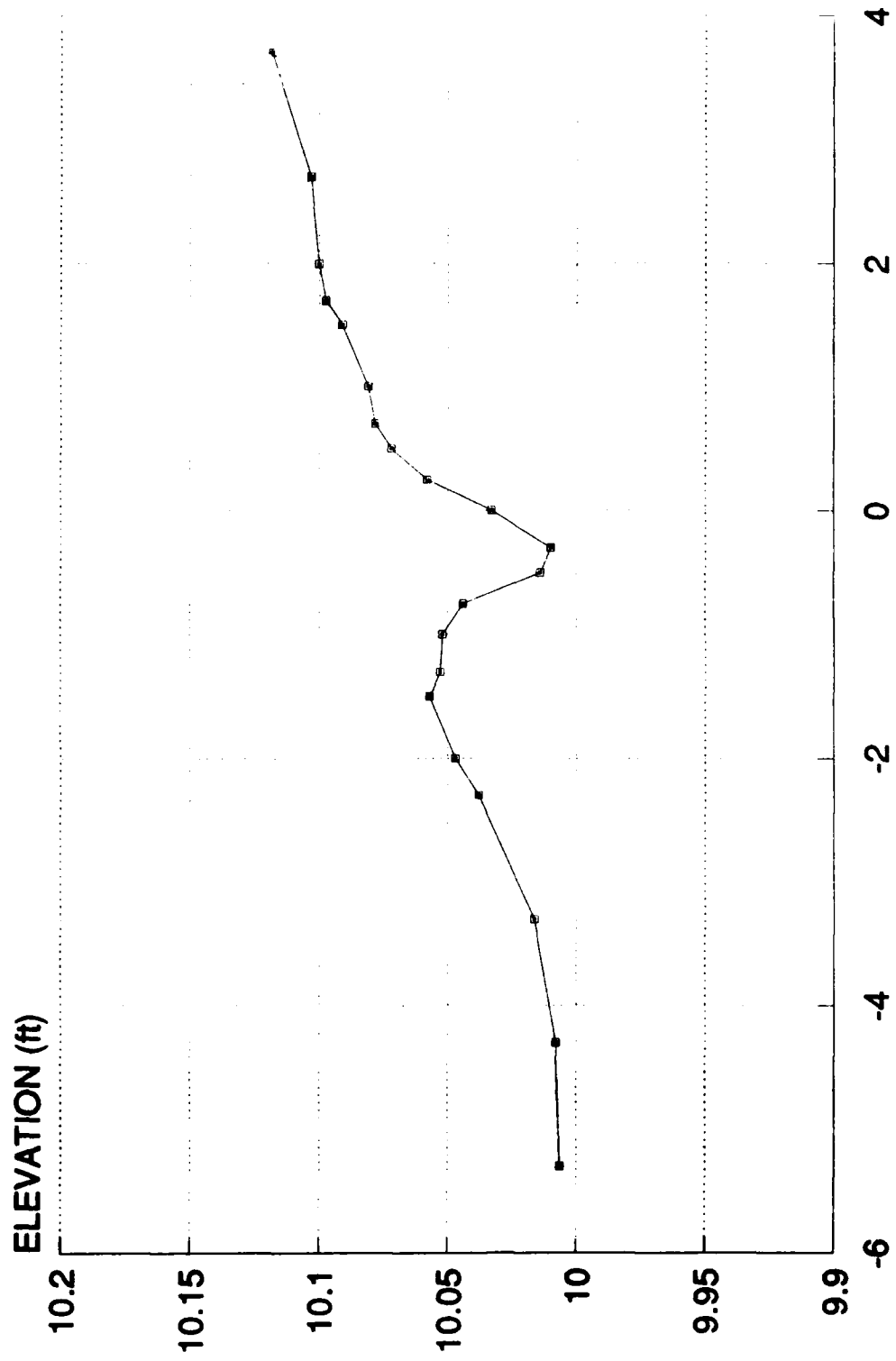
F-15 LANE, STATION 2+46 CROSS-SECTION AFTER 6000 PASSES
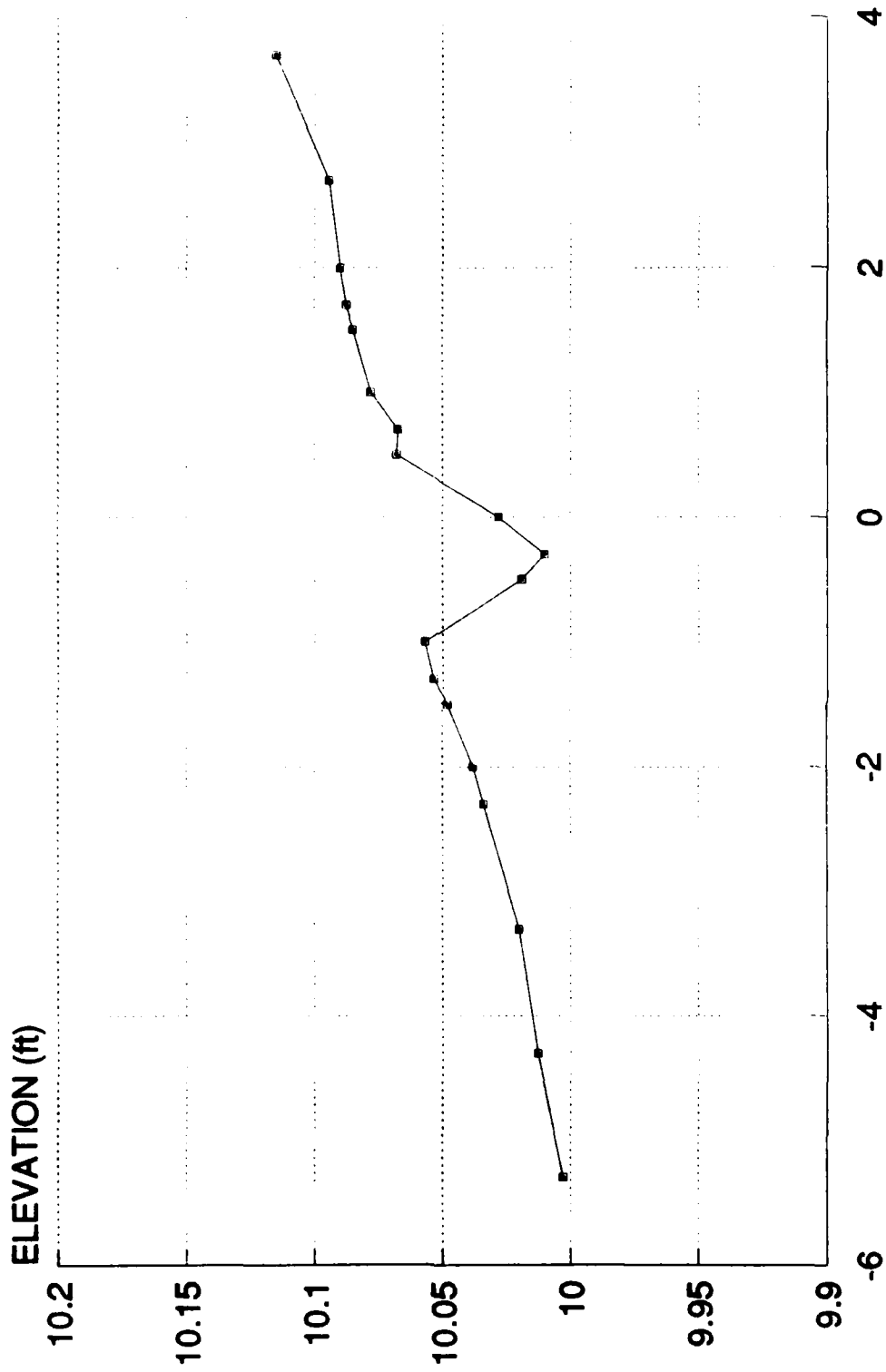
ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)

F-15 LANE, STATION 2+54 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
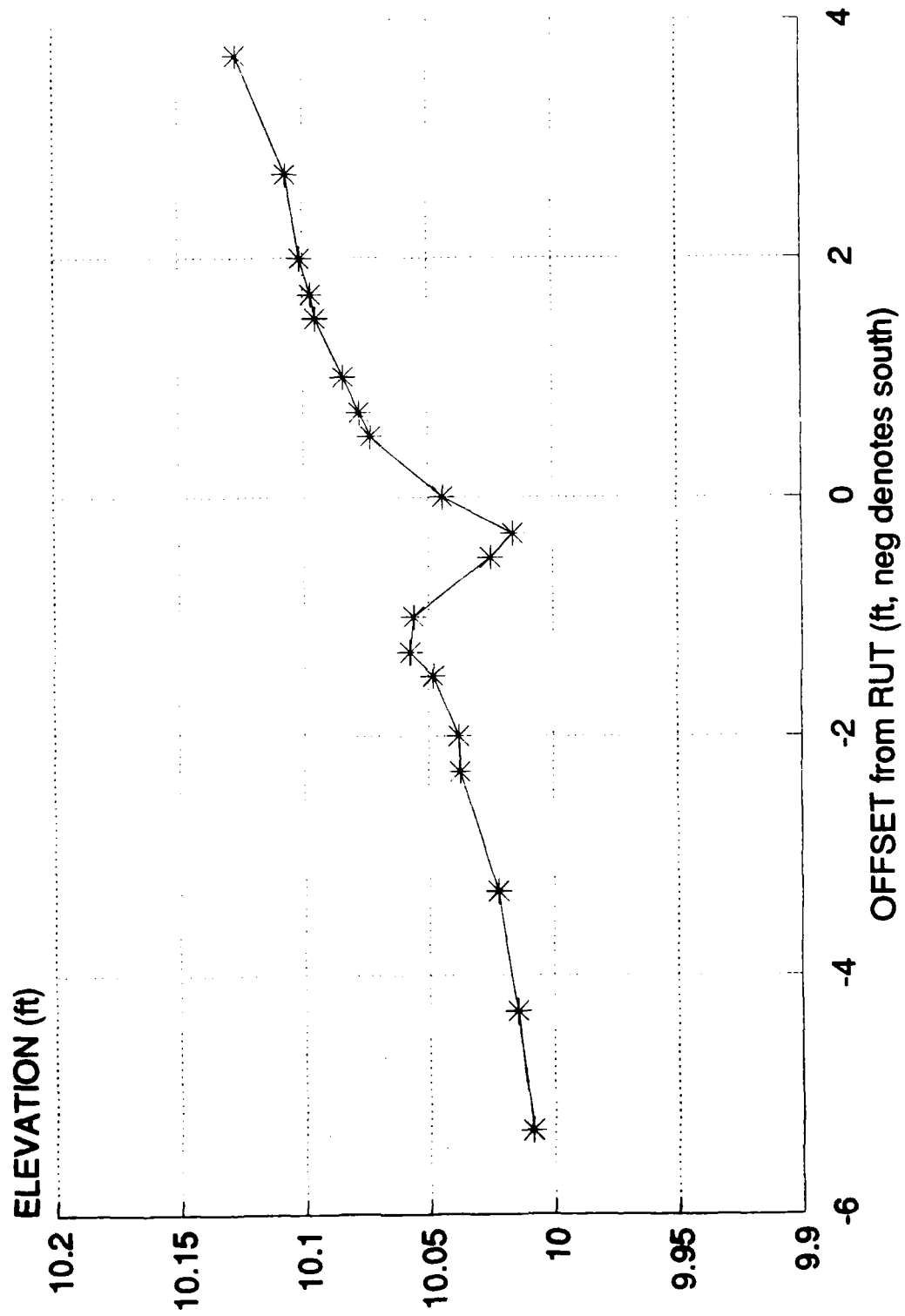
F-15 LANE, STATION 2+56 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
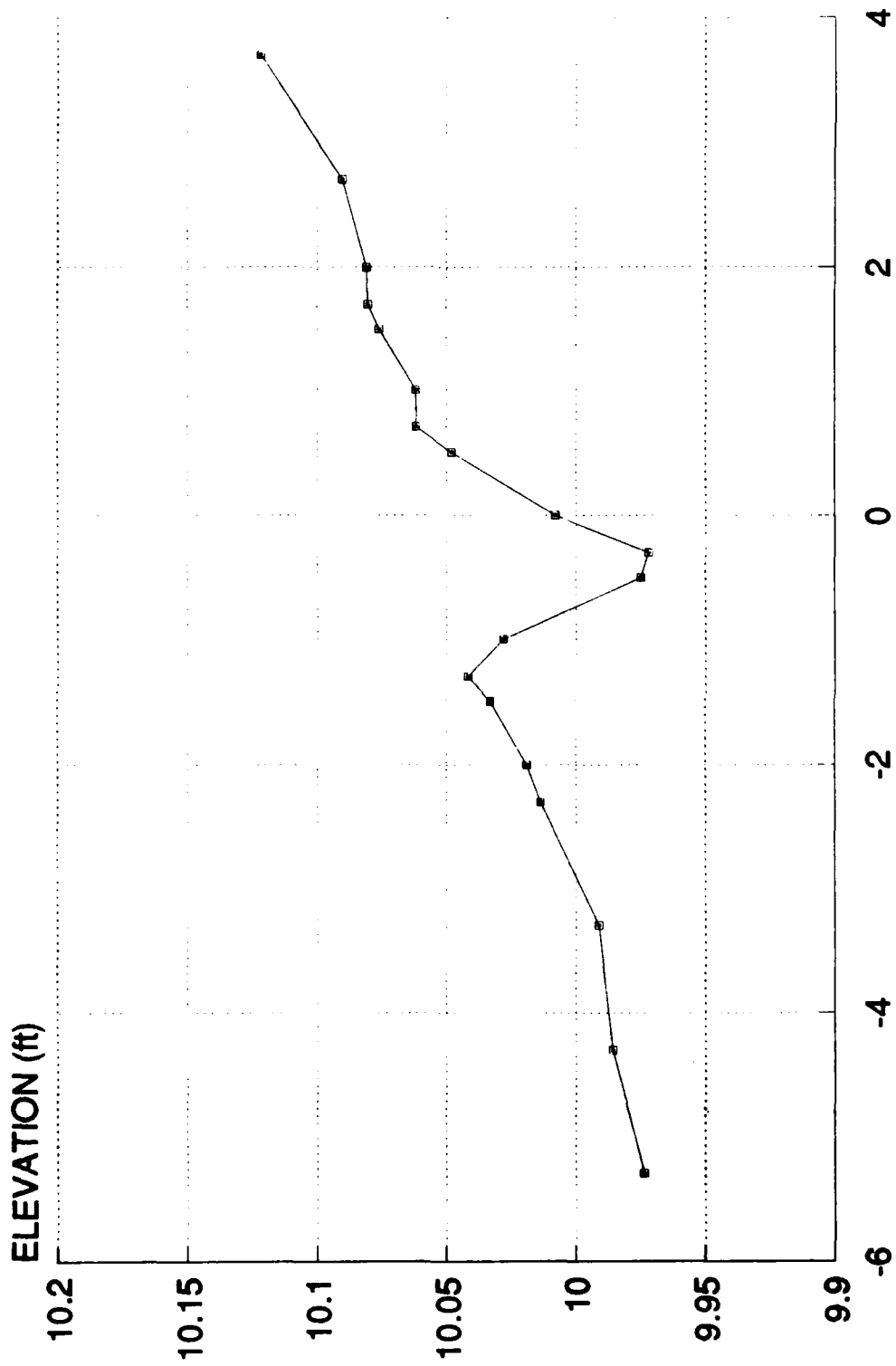
F-15 LANE, STATION 2+60 CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
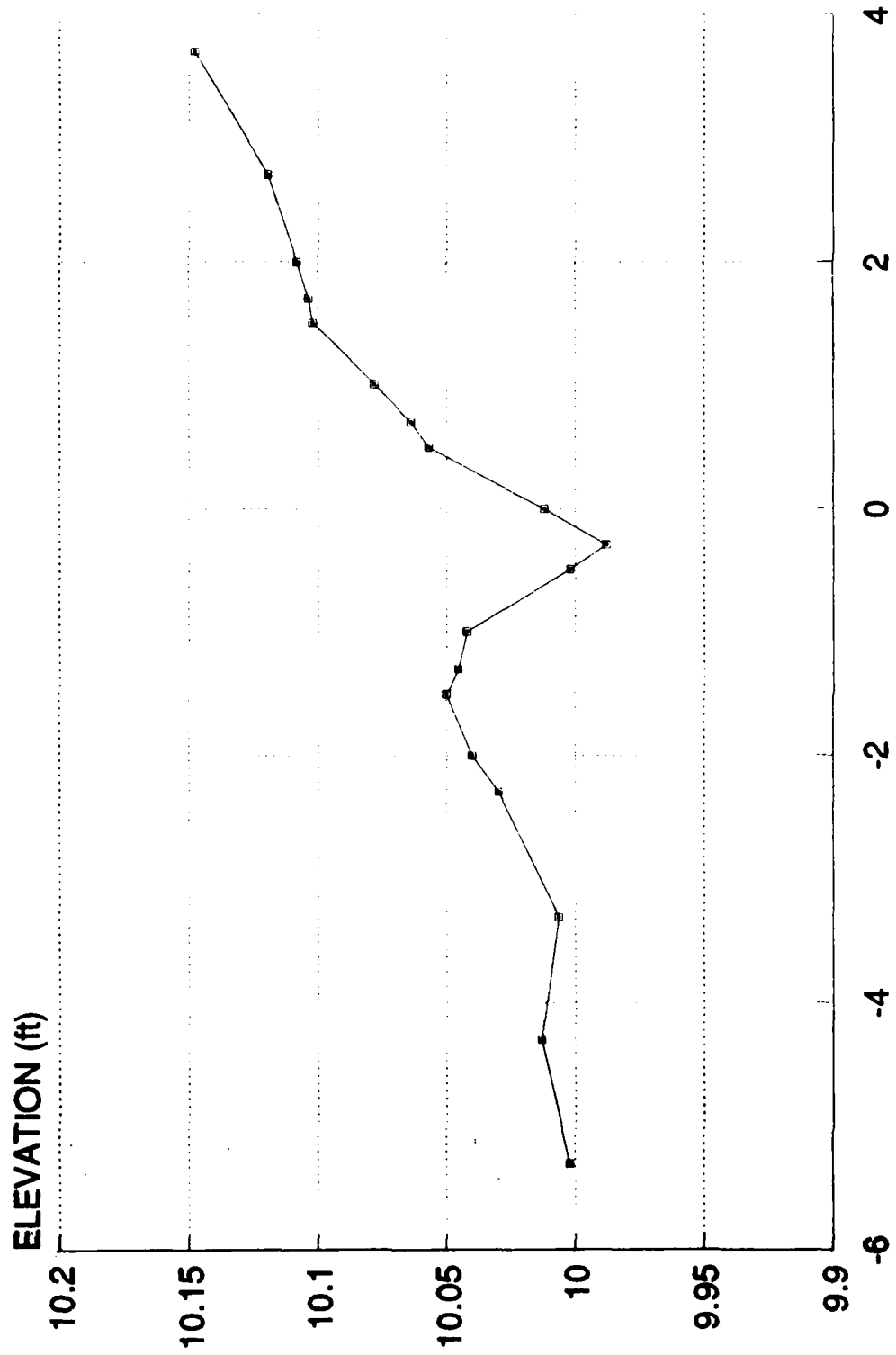
F-15 LANE, STATION 2+64 CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)

F-15 LANE, STATION 2+68 RUT CROSS-SECTION AFTER 6000 PASSES

ELEVATION (ft)

OFFSET from RUT (ft, neg denotes south)
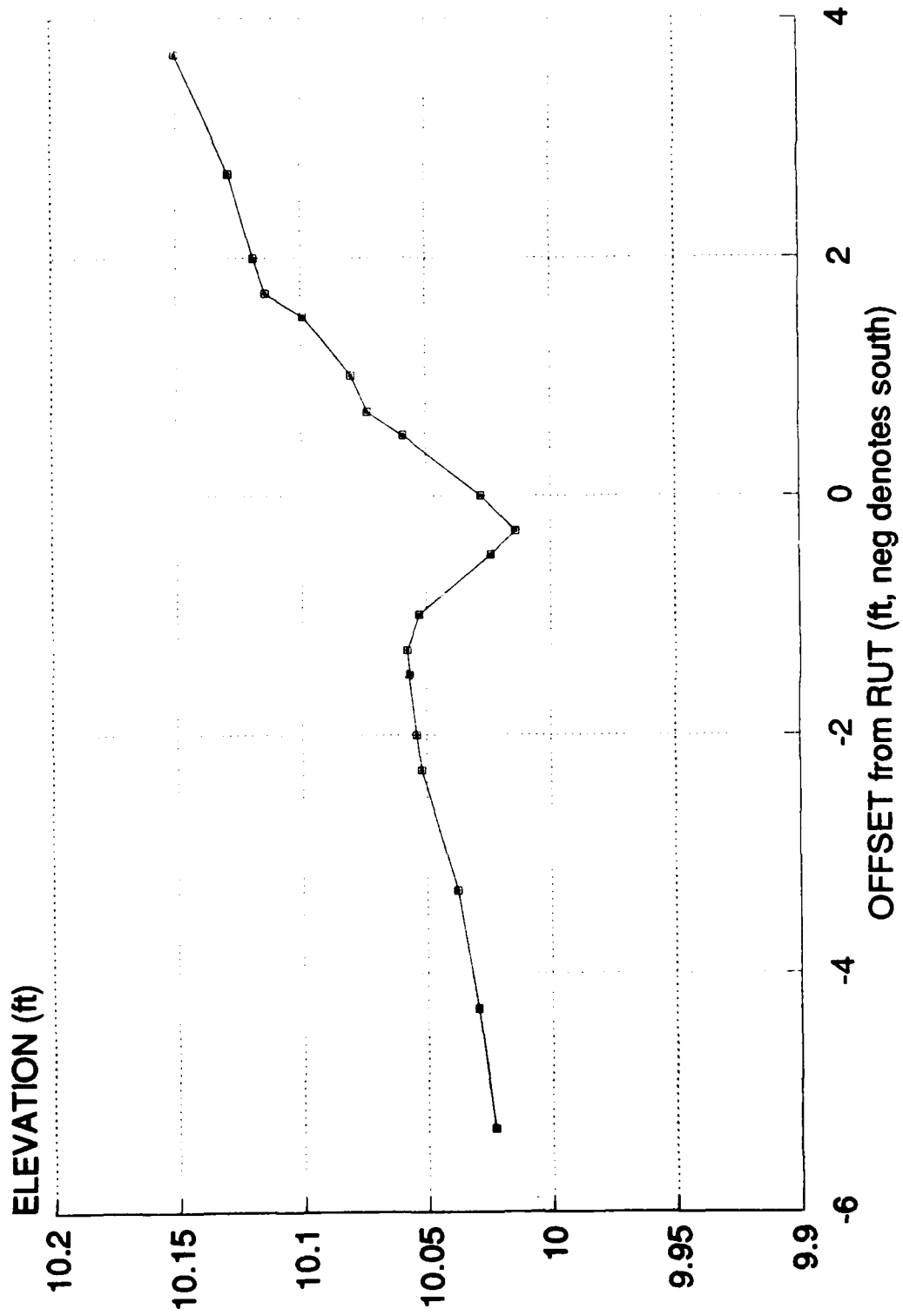
F-15 LANE, STATION 2+48 RUT SECTION AFTER 6000 PASSES
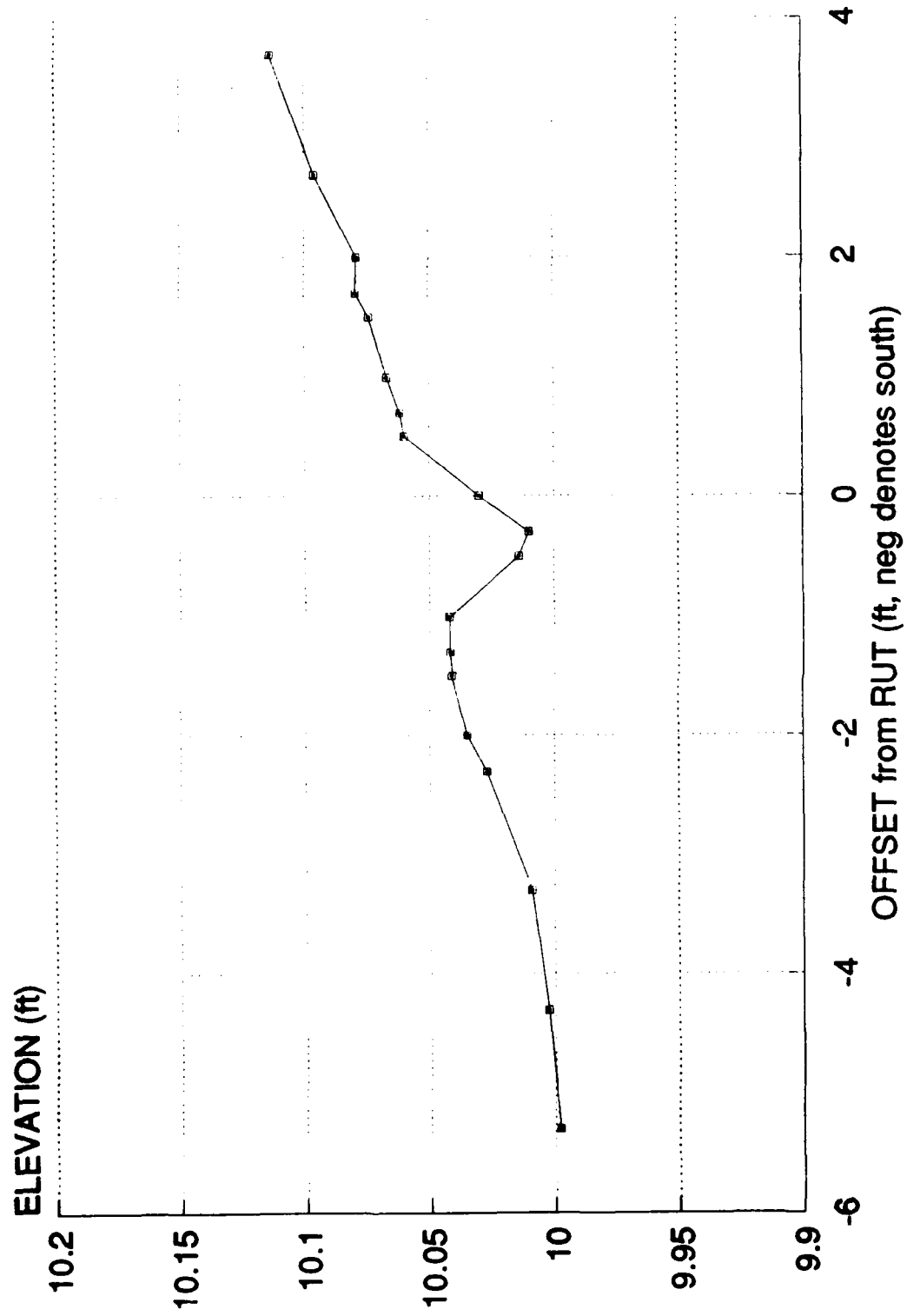
APPENDIX C

CORE MIX PROPERTIES

C1   PHYSICAL PROPERTIES

APPENDIX C1. MAT CORE PHYSICAL PROPERTIES (FILE: mydens4.cal)
LOAD 1 = F-4   LOAD 2 = F-15

LOAD	CORE	AIR	H2O	SSD	CORR'D BULK	MAT DENS	LAB RECOMPACTED DENS	%COMPN	% AC	Vac	Vcore
1	1-238N	1892.3	1117	1910.3	2.387	149.0	149.8	99.5	3.9	72.1	793.3
1	1-238S	2148.9	1262.9	2175.2	2.357	147.2	149.8	98.2	3.9	81.9	912.3
1	1-240R1	1781.1	1067.1	1787.8	2.473	154.4	149.8	103.1	3.9	67.9	720.7
1	1-238L1	1223.4	712.1	1225.2	2.386	149.0			3.9	46.6	513.1
1	1-238L2	1250.3	733.2	1252	2.412	150.6			3.9	47.6	518.8
1	1-238LN	1215.3	709.8	1216.5	2.400	149.9	149.8		3.9	46.3	506.7
1	1-244N	1984.6	1180.2	2002.2	2.416	150.9	149.2	101.1	3.9	75.8	822.0
1	1-244S	2131.5	1266.3	2154.1	2.403	150.0	149.2	100.5	3.9	81.4	887.8
1	1-244R1	1618.2	970.5	1622	2.486	155.2	149.2	104.0	3.9	61.8	651.5
1	1-244L1	1202	701.9	1203.7	2.397	149.7			3.9	45.9	501.8
1	1-244L2	1249.2	723.6	1253.2	2.361	147.4			3.9	47.7	529.6
1	1-244LN	1245	730.5	1246.7	2.414	150.7	149.2		3.9	47.5	516.2
1	1-246R	1820.7	1081.4	1821.7	2.461	153.7	150.1	102.4	4.0	70.6	740.3
1	1-246N	1892.3	1120.7	1905.7	2.413	150.6	150.1	100.3	4.0	73.4	785.0
1	1-246S	2099.6	1240.5	2127.8	2.368	147.9	150.1	98.5	4.0	81.4	887.3
1	1-246R1	1884	1123.6	1894.4	2.446	152.7	150.1	101.7	4.0	73.1	770.8
1	1-246L1	1225.3	715.3	1227.8	2.393	149.4			4.0	47.5	512.5
1	1-246L2	1228.8	721.4	1230.6	2.415	150.8	150.1		4.0	47.6	509.2
1	1-250R	1768.7	1065.9	1772.3	2.506	156.4	151.5	103.3	4.2	71.7	706.4
1	1-250N	1928.8	1149.2	1942.6	2.433	151.9	151.5	100.3	4.2	78.2	793.4
1	1-250S	2094.5	1240.6	2110.9	2.409	150.4	151.5	99.3	4.2	84.9	870.3
1	1-250R1	1871.7	1132	1876	2.518	157.2	151.5	103.8	4.2	75.9	744.0
1	1-250L2	1250.1	736.1	1254.3	2.414	150.7			4.2	50.7	518.2
1	1-250L3	1224.8	724.2	1226.3	2.441	152.4			4.2	49.6	502.1
1	1-250LN	1235.2	726.2	1237	2.420	151.1			4.2	50.1	510.8
1	1-250LS	1233.1	727	1234.3	2.433	151.9	151.5		4.2	50.0	507.3
1	1-254R	1849.4	1115.6	1852.2	2.513	156.9	153.9	101.9	4.1	73.7	736.6
1	1-254N	1992.2	1194.8	2001.6	2.471	154.3	153.9	100.3	4.1	79.4	806.8
1	1-254S	2032.4	1209	2044.9	2.433	151.9	153.9	98.7	4.1	81.0	835.9
1	1-254LN	1237.9	738.5	1240.4	2.468	154.1			4.1	49.3	501.9
1	1-254LS	1237.8	736.8	1239.7	2.463	153.8	153.9		4.1	49.3	502.9
1	1-258R	1730.6	1035.8	1733.9	2.481	154.9	153.0	101.2	3.9	65.8	698.1
1	1-258N1 (3T7-3)	2014.9	1191.1	2020.9	2.430	151.7	153.0	99.2	3.9	76.6	829.8
1	1-258N1 (3T7-4)	1948.4	1148.6	1953.1	2.424	151.3	153.0	98.9	3.9	74.0	804.5
1	1-258S	1954.9	1165.3	1979	2.404	150.1	153.0	98.1	3.9	74.3	813.7
1	1-258R1	1779.3	1070.8	1784.8	2.494	155.7	153.0	101.8	3.9	67.6	714.0
1	1-258L3	1216.3	721.1	1218.1	2.450	152.9			3.9	46.2	497.0
1	1-258L5	1224.6	733.3	1226.7	2.484	155.1			3.9	46.5	493.4
1	1-258LN	1199.7	712.1	1202	2.451	153.0			3.9	45.6	489.9
1	1-258LS	1191	700.5	1193.5	2.418	150.9	153.0		3.9	45.3	493.0

APPENDIX C1 (CONT). MAT CORE PHYSICAL PROPERTIES
LOAD 1 = F-4   LOAD 2 = F-15

LOAD	CORE	Vaggr	Vv	VTM	AVG LAB VTM	VMA	AVG LAB VMA	VF	TMD	VTM ck	%TMD	RICE TMD	RICE VTM
1	1-238N	645.2	76.03	9.6		18.7		48.7	164.6	9.5	90.5		
1	1-238S	732.7	97.77	10.7		19.7		45.6	164.6	10.6	89.4		
1	1-240R1	607.3	45.58	6.3		15.7		59.8	164.6	6.2	93.8		
1	1-238L1	417.1	49.37	9.6		18.7		48.6	164.6	9.5	90.5		
1	1-238L2	426.3	44.88	8.7		17.8		51.5	164.6	8.5	91.5		
1	1-238LN	414.4	46.05	9.1	9.1	18.2	18.3	50.1	164.6	9.0	91.0		
1	1-244N	676.6	69.62	8.5		17.7		52.1	164.6	8.3	91.7		
1	1-244S	726.7	79.73	9.0		18.2		50.5	164.6	8.9	91.1		
1	1-244R1	551.7	38.03	5.8		15.3		61.9	164.6	5.7	94.3		
1	1-244L1	409.8	46.11	9.2		18.3		49.9	164.6	9.1	90.9		
1	1-244L2	425.9	56.02	10.6		19.6		46.0	164.6	10.5	89.5		
1	1-244LN	424.4	44.21	8.6	9.4	17.8	18.6	51.8	164.6	8.4	91.6		
1	1-246R	620.3	49.38	6.7		16.2		58.8	164.4	6.5	93.5		
1	1-246N	644.7	66.91	8.5		17.9		52.3	164.4	8.4	91.6		
1	1-246S	715.3	90.55	10.2		19.4		47.3	164.4	10.1	89.9		
1	1-246R1	641.9	55.86	7.2		16.7		56.7	164.4	7.1	92.9		
1	1-246L1	417.5	47.53	9.3		18.5		50.0	164.4	9.2	90.8		
1	1-246L2	418.7	42.90	8.4	8.8	17.8	18.2	52.6	164.4	8.3	91.7		
1	1-250R	601.5	33.25	4.7		14.9		68.3	164.0	4.6	95.4		
1	1-250N	655.9	59.32	7.5		17.3		56.9	164.0	7.4	92.6		
1	1-250S	712.3	73.16	8.4		18.2		53.7	164.0	8.3	91.7		
1	1-250R1	636.5	31.65	4.3		14.4		70.6	164.0	4.1	95.9		
1	1-250L2	425.1	42.43	8.2		18.0		54.4	164.0	8.1	91.9		
1	1-250L3	416.5	35.96	7.2		17.0		58.0	164.0	7.0	93.0		
1	1-250LN	420.0	40.70	8.0		17.8		55.2	164.0	7.8	92.2		
1	1-250LS	419.3	38.00	7.5	7.7	17.3	17.5	56.8	164.0	7.4	92.6		
1	1-254R	629.4	33.54	4.6		14.6		68.7	164.1	4.4	95.6		
1	1-254N	678.0	49.45	6.1		16.0		61.6	164.1	6.0	94.0		
1	1-254S	691.7	63.27	7.6		17.3		56.1	164.1	7.4	92.6		
1	1-254LN	421.3	31.30	6.2		16.1		61.2	164.1	6.1	93.9		
1	1-254LS	421.2	32.34	6.4	6.3	16.2	16.2	60.4	164.1	6.3	93.7		
1													
1	1-258R	590.1	42.23	6.0		15.5		60.9	164.7	5.9	94.1		
1	1-258N1 (3T7-3)	687.1	66.18	8.0		17.2		53.6	164.7	7.9	92.1		
1	1-258N1 (3T7-4)	664.4	66.09	8.2		17.4		52.8	164.7	8.1	91.9		
1	1-258S	666.6	72.82	8.9		18.1		50.5	164.7	8.8	91.2		
1	1-258R1	606.7	39.67	5.6		15.0		63.0	164.7	5.4	94.6		
1	1-258L3	414.7	36.04	7.3		16.6		56.2	164.7	7.1	92.9		
1	1-258L5	417.6	29.30	5.9		15.4		61.4	164.7	5.8	94.2		
1	1-258LN	409.1	35.23	7.2		16.5		56.4	164.7	7.1	92.9		
1	1-258LS	406.1	41.63	8.4	7.2	17.6	16.5	52.1	164.7	8.3	91.7		

APPENDIX C1. MAT CORE PHYSICAL PROPERTIES (FILE: mydens4.cal)

LOAD 1 = F-4   LOAD 2 = F-15

LOAD	CORE	AIR	H2O	SSD	CORR'D BULK	MAT DENS	LAB DENS	RECOMPACTED %COMPN	% AC	Vac	Vcore
1	1-260RY	1685.2	1005	1686.2	2.476	154.6	151.8	101.8	4.0	65.5	681.2
1	1-260N	1878.5	1120.3	1891.8	2.437	152.1	151.8	100.2	4.0	73.0	771.5
1	1-260S	2101	1246.2	2119	2.409	150.4	151.8	99.1	4.0	81.7	872.8
1	1-260R1	1894	1137	1900.5	2.483	155.0	151.8	102.1	4.0	73.6	763.5
1	1-260L1	1217.6	718.3	1219.4	2.432	151.8			4.0	47.3	501.1
1	1-260L2	1233.9	728.6	1235.7	2.435	152.0			4.0	48.0	507.1
1	1-260LJ	1221.6	716.7	1223.2	2.414	150.7			4.0	47.5	506.5
1	1-260LS	1209.8	715.8	1211.3	2.444	152.6	151.8		4.0	47.0	495.5
1	1-265RY	1764.8	1047.9	1766.2	2.459	153.5	151.5	101.3	4.4	74.8	718.3
1	1-264N	1900.1	1135	1912.5	2.446	152.7	151.5	100.8	4.4	80.5	777.5
1	1-264S	2024.5	1199.7	2044.3	2.399	149.8	151.5	98.9	4.4	85.8	844.6
1	1-264R1	1609.1	961.8	1613.8	2.470	154.2	151.5	101.8	4.4	68.2	652.0
1	1-264L3	1218.8	725.4	1220.9	2.462	153.7			4.4	51.6	495.5
1	1-265L4	1273.4	747.1	1275.5	2.412	150.6			4.4	54.0	528.4
1	1-264LR	1238.8	724.8	1240.4	2.405	150.1	151.5		4.4	52.5	515.6
1	1-268R	1792.1	1060	1795.7	2.438	152.2	150.9	100.9	4.1	70.7	735.7
1	1-268N	1704.8	1015.4	1712.9	2.446	152.7	150.9	101.2	4.1	67.3	697.5
1	1-268S	2033.1	1199.6	2052	2.387	149.0	150.9	98.8	4.1	80.2	852.4
1	1-268R1	1838.3	1090	1847.1	2.430	151.7	150.9	100.5	4.1	72.5	757.1
1	1-268L2	1240.7	730.5	1245.3	2.412	150.6			4.1	49.0	514.8
1	1-268L3	1193.9	699.8	1195.7	2.410	150.5			4.1	47.1	495.9
1	1-268LR	1184.9	698.3	1187.4	2.425	151.4			4.1	46.8	489.1
1	1-268L5	1261.3	737.2	1262	2.405	150.2			4.1	49.8	524.8
1	1-268LN	1226.4	723.9	1228.1	2.434	152.0	150.9		4.1	48.4	504.2
2	2-238R	1721.5	1039.6	1722.4	2.523	157.5	156.2	100.9	4.0	66.1	682.8
2	2-238R	1672.3	1009.3	1672.9	2.522	157.5	156.2	100.8	4.0	64.2	663.6
2	2-238R	1720.9	1040.8	1721.5	2.530	158.0	156.2	101.1	4.0	66.1	680.7
2	2-238N	2065.4	1227.9	2081.2	2.423	151.2	156.2	96.8	4.0	79.3	853.3
2	2-238SA	2043.7	1229.8	2048.8	2.497	155.9	156.2	99.8	4.0	78.5	819.0
2	2-238SB	2026.5	1223.3	2031.5	2.510	156.7	156.2	100.3	4.0	77.8	808.2
2	2-238L2X	1205.5	724.8	1208.9	2.492	155.6			4.0	46.3	484.1
2	2-238LAU	1195.5	719	1197.1	2.503	156.2			4.0	45.9	478.1
2	2-238LAE	1194.3	722.3	1196.3	2.522	157.4			4.0	45.8	474.0
2	2-238LAE	1181.9	709.3	1184.4	2.490	155.4	156.2		4.0	45.4	475.1
2	2-245R	1795.3	1092.8	1797.2	2.551	159.2	154.7	102.9	3.8	66.3	704.4
2	2-245R1	1843.2	1124.8	1844.8	2.562	160.0	154.7	103.4	3.8	68.1	720.0
2	2-246N	2185	1307.8	2193	2.470	154.2	154.7	99.7	3.8	80.7	885.2
2	2-244S	2084.9	1255.5	2089.2	2.503	156.3	154.7	101.0	3.8	77.0	833.7
2	2-246L1	1193.6	718.8	1199.2	2.487	155.2			3.8	44.1	480.4
2	2-246L2	1227.9	732.2	1234.5	2.447	152.7			3.8	45.3	502.3
2	2-245LR	1208.3	727.6	1209.6	2.509	156.6			3.8	44.6	482.0
2	2-246LA	1214.8	726.6	1216.4	2.482	155.0			3.8	44.9	489.8
2	2-246LB	1228.2	731.4	1230.7	2.462	153.7	154.7		3.8	45.4	499.3

APPENDIX C1 (CONT). MAT CORE PHYSICAL PROPERTIES
LOAD 1 = F-4   LOAD 2 = F-15

| | | | | | AVG LAB | | AVG LAB | CALCULATED | | | | RICE | RICE |
LOAD	CORE	Vaggr	Vv	VTM	VTM	VMA	VMA	VF	TMD	VTM ck	%TMD	TMD	VTM
1	1-260RY	574.1	41.60	6.1		15.7		61.2	164.4	6.0	94.0		
1	1-260N	639.9	58.53	7.6		17.1		55.5	164.4	7.5	92.5		
1	1-260S	715.7	75.39	8.6		18.0		52.0	164.4	8.5	91.5		
1	1-260R1	645.2	44.65	5.8		15.5		62.2	164.4	5.7	94.3		
1	1-260L1	414.8	38.97	7.8		17.2		54.8	164.4	7.7	92.3		
1	1-260L2	420.3	38.79	7.6		17.1		55.3	164.4	7.5	92.5		
1	1-260LJ	416.2	42.85	8.5		17.8		52.6	164.4	8.3	91.7		
1	1-260LS	412.1	36.33	7.3	7.8	16.8	17.2	56.4	164.4	7.2	92.8		
1	1-265RY	599.0	44.57	6.2		16.6		62.7	163.5	6.1	93.9		
1	1-264N	644.9	52.12	6.7		17.1		60.7	163.5	6.6	93.4		
1	1-264S	687.1	71.73	8.5		18.6		54.5	163.5	8.4	91.6		
1	1-264R1	546.1	37.71	5.8		16.2		64.4	163.5	5.7	94.3		
1	1-264L3	413.6	30.21	6.1		16.5		63.1	163.5	6.0	94.0		
1	1-265L4	432.2	42.27	8.0		18.2		56.1	163.5	7.9	92.1		
1	1-264LR	420.4	42.67	8.3	7.5	18.5	17.7	55.2	163.5	8.2	91.8		
1	1-268R	610.1	54.86	7.5		17.1		56.3	164.2	7.3	92.7		
1	1-268N	580.4	49.83	7.1		16.8		57.4	164.2	7.0	93.0		
1	1-268S	692.2	80.00	9.4		18.8		50.1	164.2	9.3	90.7		
1	1-268R1	625.9	58.71	7.8		17.3		55.3	164.2	7.6	92.4		
1	1-268L2	422.4	43.45	8.4		17.9		53.0	164.2	8.3	91.7		
1	1-268L3	406.5	42.33	8.5		18.0		52.7	164.2	8.4	91.6		
1	1-268LR	403.4	38.94	8.0		17.5		54.6	164.2	7.8	92.2		
1	1-268L5	429.4	45.62	8.7		18.2		52.2	164.2	8.6	91.4		
1	1-268LN	417.5	38.28	7.6	8.2	17.2	17.8	55.8	164.2	7.5	92.5		
2	2-238R	586.8	29.95	4.4		14.1		68.8	164.5	4.3	95.7		
2	2-238R	570.0	29.41	4.4		14.1		68.6	164.5	4.3	95.7		
2	2-238R	586.6	28.08	4.1		13.8		70.2	164.5	4.0	96.0		
2	2-238N	704.0	70.04	8.2		17.5		53.1	164.5	8.1	91.9		
2	2-238SA	696.6	43.96	5.4		14.9		64.1	164.5	5.2	94.8		
2	2-238SB	690.7	39.69	4.9		14.5		66.2	164.5	4.8	95.2		
2	2-238L2X	410.9	26.94	5.6		15.1		63.2	164.5	5.4	94.6		
2	2-238LAU	407.5	24.73	5.2		14.8		65.0	164.5	5.0	95.0		
2	2-238LAE	407.1	21.08	4.4		14.1		68.5	164.5	4.3	95.7		
2	2-238LAE	402.8	26.89	5.7	5.2	15.2	14.8	62.8	164.5	5.5	94.5		
2	2-245R	612.9	25.23	3.6		13.0		72.4	164.9	3.5	96.5		
2	2-245R1	629.2	22.71	3.2		12.6		75.0	164.9	3.0	97.0		
2	2-246N	745.9	58.60	6.6		15.7		57.9	164.9	6.5	93.5		
2	2-244S	711.7	44.97	5.4		14.6		63.1	164.9	5.3	94.7		
2	2-246L1	407.5	28.85	6.0		15.2		60.4	164.9	5.9	94.1		
2	2-246L2	419.2	37.78	7.5		16.5		54.6	164.9	7.4	92.6		
2	2-245LR	412.5	24.89	5.2		14.4		64.2	164.9	5.0	95.0		
2	2-246LA	414.7	30.23	6.2		15.3		59.7	164.9	6.0	94.0		
2	2-246LB	419.3	34.66	6.9	6.4	16.0	15.5	56.7	164.9	6.8	93.2		

APPENDIX C1. MAT CORE PHYSICAL PROPERTIES (FILE: aydens4.cal)
LOAD 1 = F-4   LOAD 2 = F-15

LOAD	CORE	AIR	H2O	SSD	BULK	CORR'D DENS	MAT DENS	LAB RECOMPACTED %COMPN	% AC	Vac	Vcore
2	2-248R	1833.1	1115.3	1835.1	2.549	159.1	155.9	102.1	4.0	71.4	719.8
2	2-248N	2155.5	1297.5	2162	2.495	155.8	155.9	99.9	4.0	84.0	864.5
2	2-248S	2050.7	1235.3	2055	2.504	156.3	155.9	100.3	4.0	79.9	819.7
2	2-248R1	1776.7	1080.6	1778.7	2.547	159.0	155.9	102.0	4.0	69.2	698.1
2	2-248L1	1247.9	750	1249.4	2.501	156.1			4.0	48.6	499.4
2	2-248L2	1239.8	742.9	1241.9	2.487	155.2			4.0	48.3	499.0
2	2-248LN	1228.8	734.6	1230.7	2.479	154.8			4.0	47.9	496.1
2	2-248LS	1197.4	723.7	1198.6	2.523	157.5	155.9		4.0	46.7	474.9
2	2-255R	1854.9	1124.2	1856.9	2.534	158.2	154.7	102.2	3.8	69.0	732.7
2	2-254R1	1900.8	1157.3	1902.1	2.554	159.5	154.7	103.1	3.8	70.7	744.8
2	2-254N	2212.9	1332	2219.3	2.496	155.8	154.7	100.7	3.8	82.4	887.3
2	2-254S (1T6-1)	1220.3	721.8	1221.8	2.443	152.5	154.7	98.6	3.8	45.4	500.0
2	2-254L2	1241	742.9	1244.4	2.477	154.6			3.8	46.2	501.5
2	2-255L3	1333.9	797	1335.7	2.478	154.7			3.8	49.6	538.7
2	2-255L4	1316.9	787.7	1319.2	2.480	154.8	154.7		3.8	49.0	531.5
2	2-256N	2202	1324.3	2209.2	2.491	155.5	154.2	100.8	3.8	81.7	884.9
2	2-256S (1T6-2)	1221.4	726.7	1222.8	2.464	153.8	154.2	99.8	3.8	45.3 .0	496.1
2	2-256S (1T6-3)	2041.4	1217.6	2049.3	2.457	153.4	154.2	99.5	3.8	75.8 .0	831.7
2	2-256R	1851.2	1129.5	1856.9	2.547	159.0	154.2	103.1	3.8	68.7	727.4
2	2-257L2X	1217.9	731.4	1222.2	2.484	155.0			3.8	45.2	490.8
2	2-256LN	1247.7	746.2	1250.6	2.476	154.6			3.8	46.3	504.4
2	2-256LS (1T6-3)	1213.7	721.1	1216.8	2.451	153.0	154.2		3.8	45.1	495.7
2	2-261R	1650.4	1001	1653.8	2.530	158.0	154.8	102.0	3.8	60.8	652.8
2	2-260N	2190.9	1313	2201.9	2.467	154.0	154.8	97.5	3.8	80.7	888.9
2	2-260S (1T6-8)	2100.8	125u.4	2108.1	2.451	153.0	154.8	98.9	3.8	77.4	857.7
2	2-260S (1T6-9)	2072.8	1232.9	2081	2.446	152.7	154.8	98.6	3.8	76.3	848.1
2	2-260L1	1237.4	742.7	1240.6	2.487	155.3			3.8	45.6	497.9
2	2-260L2	1244.6	747.7	1248.1	2.489	155.4			3.8	45.8	500.4
2	2-261L3	1212.4	730.4	1214.1	2.509	156.6			3.8	44.7	483.7
2	2-261L4	1204.8	724.6	1207.4	2.498	155.9			3.8	44.4	482.8
2	2-260LN	1222.5	727.8	1225.5	2.458	153.5			3.8	45.0	497.7
2	2-260LN	1245.7	741	1248	2.459	153.5			3.8	45.9	507.0
2	2-260LS (1T6-8)	1152.5	693.8	1154.4	2.504	156.3			3.8	42.4	460.6
2	2-260LN	1211.4	715.7	1213.4	2.436	152.1	154.8		3.8	44.6	497.7

APPENDIX C1 (CONT). MAT CORE PHYSICAL PROPERTIES
LOAD 1 = F-4   LOAD 2 = F-15

LOAD	CORE	Vaggr	Vv	VTM	AVG LAB VTM	VMA	AVG LAB VMA	VF	TMD	VTM ck	%TMD	RICE TMD	RICE VTM
2	2-248R	624.4	23.95	3.3		13.3		74.9	164.4	3.2	96.8		
2	2-248N	734.2	46.27	5.4		15.1		64.5	164.4	5.2	94.8		
2	2-248S	698.5	41.25	5.0		14.8		66.0	164.4	4.9	95.1		
2	2-248R1	605.2	23.66	3.4		13.3		74.5	164.4	3.3	96.7		
2	2-248L1	425.1	25.70	5.1		14.9		65.4	164.4	5.0	95.0		
2	2-248L2	422.3	28.37	5.7		15.4		63.0	164.4	5.6	94.4		
2	2-248LN	418.6	29.65	6.0		15.6		61.8	164.4	5.9	94.1		
2	2-248LS	407.9	20.37	4.3	5.3	14.1	15.0	69.6	164.4	4.2	95.8		
2	2-255R	633.0	30.64	4.2		13.6		69.3	164.9	4.1	95.9		
2	2-254R1	648.7	25.36	3.4		12.9		73.6	164.9	3.3	96.7		
2	2-254N	755.2	49.74	5.6		14.9		62.3	164.9	5.5	94.5		
2	2-254S (1T6-1)	416.5	38.13	7.6		16.7		54.4	164.9	7.5	92.5		
2	2-254L2	423.5	31.79	6.3		15.6		59.2	164.9	6.2	93.8		
2	2-255L3	455.2	33.83	6.3		15.5		59.5	164.9	6.2	93.8		
2	2-255L4	449.4	33.07	6.2	6.3	15.4	15.5	59.7	164.9	6.1	93.9		
2	2-256N	751.6	51.60	5.8		15.1		61.3	164.9	5.7	94.3		
2	2-256S (1T6-2)	416.9	33.89	6.8		16.0		57.2	164.9	6.7	93.3		
2	2-256S (1T6-3)	696.7	59.17	7.1		16.2		56.2	164.9	7.0	93.0		
2	2-256R	631.8	26.85	3.7		13.1		71.9	164.9	3.6	96.4		
2	2-257L2X	415.7	29.91	6.1		15.3		60.2	164.9	6.0	94.0	163.4	5.1
2	2-256LN	425.8	32.23	6.4		15.6		59.0	164.9	6.3	93.7		
2	2-256LS (1T6-3)	414.2	36.40	7.3	6.6	16.4	15.8	55.3	164.9	7.2	92.8		
2	2-261R	563.5	28.55	4.4		13.7		68.0	165.0	4.2	95.8		
2	2-260N	748.0	60.20	6.8		15.9		57.3	165.0	6.6	93.4		
2	2-260S (1T6-8)	717.2	63.08	7.4		16.4		55.1	165.0	7.2	92.8		
2	2-260S (1T6-9)	707.7	64.08	7.6		16.6		54.4	165.0	7.4	92.6		
2	2-260L1	422.5	29.86	6.0		15.2		60.4	165.0	5.9	94.1		
2	2-260L2	424.9	29.64	5.9		15.1		60.7	165.0	5.8	94.2		
2	2-261L3	413.9	25.12	5.2		14.4		64.0	165.0	5.0	95.0		
2	2-261L4	411.3	27.09	5.6		14.8		62.1	165.0	5.5	94.5		
2	2-260LN	417.4	35.30	7.1		16.1		56.1	165.0	7.0	93.0		
2	2-260LN	425.3	35.82	7.1		16.1		56.2	165.0	6.9	93.1		
2	2-260LS (1T6-8)	393.5	24.67	5.4		14.6		63.2	165.0	5.2	94.8		
2	2-260LN	413.6	39.49	7.9	6.3	16.9	15.4	53.0	165.0	7.8	92.2		

APPENDIX C1. MAT CORE PHYSICAL PROPERTIES (FILE: mydens4.cal)

LOAD 1 = F-4   LOAD 2 = F-15

LOAD	CORE	AIR	H2O	SSD	CORR'D BULK	MAT DENS	LAB DENS	RECOMPACTED %COMPN	% AC	Vac	Vcore
2	2-264ADV	1901.2	1145.1	1905.4	2.503	156.2	154.4	101.2	3.6	66.0	760.3
2	2-264R	1710.8	1033.5	1712.3	2.522	157.5	154.4	102.0	3.6	59.4	678.8
2	2-264N	2065	1225.2	2084.2	2.406	150.2	154.4	97.3	3.6	71.6	859.0
2	2-264S	1862	1111.6	1872.1	2.450	153.0	154.4	99.1	3.6	64.6	760.5
2	2-264LN	1222.2	734.3	1223.2	2.502	156.2			3.6	42.4	488.9
2	2-264LS	1237.3	741.7	1239.5	2.488	155.3			3.6	42.9	497.8
2	2-264LN1	1240.6	738.9	1243.7	2.460	153.6			3.6	43.0	504.8
2	2-264LS1	1221.6	723.4	1224.2	2.441	152.4	154.4		3.6	42.4	500.8
2	2-268SDV	1835.7	1100.6	1842.9	2.475	154.5	153.9	100.4	3.5	63.2	742.3
2	2-268R	1638.2	980.7	1641.5	2.481	154.9	153.9	100.7	3.5	56.4	660.8
2	2-268N	2064.3	1219.5	2087.1	2.381	148.7	153.9	96.6	3.5	71.0	867.6
2	2-268S	1807.8	1073.3	1822.1	2.416	150.8	153.9	98.0	3.5	62.2	748.8
2	2-268LN	1185.7	703.8	1187.8	2.452	153.1			3.5	40.8	484.0
2	2-268LS	1179.3	704.7	1181	2.478	154.7	153.9		3.5	40.6	476.3

APPENDIX C1 (CONT). MAT CORE PHYSICAL PROPERTIES

LOAD 1 = F-4   LOAD 2 = F-15

LOAD	CORE	Vaggr	Vv	VTM	AVG LAB VTM	VMA	AVG LAB VMA	VF	TMD	VTM ck	%TMD	RICE TMD	RICE VTM
2	2-264ADV	650.6	43.76	5.8		14.4		60.1	165.6	5.6	94.4		
2	2-264R	585.4	34.02	5.0		13.8		63.6	165.6	4.9	95.1		
2	2-264N	706.6	80.73	9.4		17.7		47.0	165.6	9.3	90.7		
2	2-264S	637.2	58.74	7.7		16.2		52.4	165.6	7.6	92.4		
2	2-264LN	418.2	28.27	5.8		14.5		60.0	165.6	5.7	94.3		
2	2-264LS	423.4	31.48	6.3		14.9		57.7	165.6	6.2	93.8		
2	2-264LN1	424.5	37.23	7.4		15.9		53.6	165.6	7.3	92.7		
2	2-264LS1	418.0	40.39	8.1	6.9	16.5	15.5	51.2	165.6	7.9	92.1		
2	2-268SDV	628.4	50.79	6.8		15.3		55.4	165.6	6.7	93.3		
2	2-268R	560.8	43.69	6.6		15.1		56.3	165.6	6.5	93.5		
2	2-268N	706.6	89.97	10.4		18.6		44.1	165.6	10.3	89.7		
2	2-268S	618.8	67.80	9.1		17.4		47.8	165.6	8.9	91.1		
2	2-268LN	405.9	37.34	7.7		16.1		52.2	165.6	7.6	92.4		
2	2-268LS	403.7	32.06	6.7	7.2	15.2	15.7	55.9	165.6	6.6	93.4		

C2   EXTRACTION DATA

APPENDIX C2. EXTRACTION DATA (FILE: EXTRACT1.CAL)

CORE	DRY WGT BEFORE EXTRACTION				DRY WGT AFTER EXT. CTION		
	MIX, BOWL & FILTER	FILTER	BOWL	SMM EXTR BOWL	AGG, BOWL & FILTER	FILTER	SMM BOWL W/FINES
1-238	2857.7	17.9	1947.5	137.7	2811.8	20.7	149.4
1-239RUT	3323.2	18.1	2084.2	137.8	3262.5	20.3	149.4
1-244	4120.2	17.9	2142.5	133.5	4020.7	20.4	156
1-246	4078.9	18	2060.8	132.9	3978.9	20.7	153.1
1-250RUT	3138.4	18	2060.8	138	3083.2	20.8	148.8
1-250S,R	4145.6	18.1	2142.7	138	4035.6	20.5	165.6
1-254S	3692	18.1	2084.4	137.8	3608.5	20.8	156.1
1-254S,N	2580.7	18.4	1947.6	142.2	2547.9	20.9	149.8
1-258RUT	3468.6	18	1947.6	138.1	3390	21.1	156.3
1-258N	3448.5	17.6	2084.4	137.7	3381.6	20.5	153.5
1-258S,R	3485.6	18.1	2060.7	136.6	3419.9	20.8	147.4
1-260	4025.3	17.6	2031.7	137.1	3929	20.6	153.9
1-260S,R	3192.7	18.1	2031.6	137.9	3136.4	20.8	148.6
1-264N	3559.5	18.2	2084.5	137.7	3478.7	20.7	154.7
1-264S	3573.8	18	2060.6	132.9	3493.1	20.7	148.8
1-268RUT	3438.7	18	2084.3	137.9	3359.4	19.9	163
2-238A/E	3366.1	17.9	1947.5	133.2	3297	20.6	146.2
2-238AU	3295	18.1	2084.4	137.8	3227.7	21.8	158.7
2-244S,5J	2912.5	18.1	2084.4	137.9	2868.7	20.3	151.5
2-246N	4336.7	18.1	2031.5	136.9	4214.5	22	170.6
2-248RUT	3314.7	18.5	2060.9	137.8	3244.8	20.9	156.4
2-248N,S	2710.6	18.1	1947.6	137.9	2672.7	20.6	147
2-254N	3706.9	18.4	2084.3	137.9	3624.4	21.4	159
2-256R	3748.9	18.2	2031.5	136.9	3661.9	22.3	159
2-260C	3291.2	17.3	2031.5	136.9	3227.3	20.5	149.3
2-260N,C	2730.1	18.2	2031.5	133.4	2695.9	20.6	142.3
2-260S	3379.2	18.1	2142.5	132.9	3319.9	20.8	149.5
2-264	3881.1	18	2060.7	137.9	3801.8	21	152.9
2-268	3276.2	18.1	1947.7	138	3215.4	20.5	152.4

APPENDIX C2 (CONT). EXTRACTION DATA

CORE	WGT AGGR	WGT -200 in SMM	TOTAL AGGR	WGT -200 in FILTER	TOTAL WT FINES	TOTAL WGT MIX	% AC
1-238	846.4	11.7	858.1	2.8	14.5	892.3	3.83
1-239RUT	1160.2	11.6	1,171.8	2.2	13.8	1220.9	4.02
1-244	1860.3	22.5	1,882.8	2.5	25	1959.8	3.93
1-246	1900.1	20.2	1,920.3	2.7	22.9	2000.1	3.99
1-250RUT	1004.4	10.8	1,015.2	2.8	13.6	1059.6	4.19
1-250S,R	1874.8	27.6	1,902.4	2.4	30	1984.8	4.15
1-254S	1506	18.3	1,524.3	2.7	21	1589.5	4.10
1-254S,N	581.9	7.6	589.5	2.5	10.1	614.7	4.10
1-258RUT	1424.4	18.2	1,442.6	3.1	21.3	1503	4.02
1-258N	1279.6	15.8	1,295.4	2.9	18.7	1346.5	3.80
1-258S,R	1341.1	10.8	1,351.9	2.7	13.5	1406.8	3.90
1-260	1879.7	16.8	1,896.5	3	19.8	1976	4.02
1-260S,R	1086.7	10.7	1,097.4	2.7	13.4	1143	3.99
1-264N	1376	17.0	1,393.0	2.5	19.5	1456.8	4.38
1-264S	1414.5	15.9	1,430.4	2.7	18.6	1495.2	4.33
1-268RUT	1257.1	25.1	1,282.2	1.9	27	1336.4	4.06
2-238A/E	1331.6	13.0	1,344.6	2.7	15.7	1400.7	4.01
2-238AU	1125.2	20.9	1,146.1	3.7	24.6	1192.5	3.89
2-244S,5J	766.2	13.6	779.8	2.2	15.8	810	3.73
2-246N	2164.9	33.7	2,198.6	3.9	37.6	2287.1	3.87
2-248RUT	1165.4	18.6	1,184.0	2.4	21	1235.3	4.15
2-248N,S	707	9.1	716.1	2.5	11.6	744.9	3.87
2-254N	1521.7	21.1	1,542.8	3	24.1	1604.2	3.83
2-256R	1612.2	22.1	1,634.3	4.1	26.2	1699.2	3.82
2-260C	1178.5	12.4	1,190.9	3.2	15.6	1242.4	4.15
2-260N,C	646.2	8.9	655.1	2.4	11.3	680.4	3.72
2-260S	1159.3	16.6	1,175.9	2.7	19.3	1218.6	3.50
2-264	1723.1	15.0	1,738.1	3	18	1802.4	3.57
2-268	1249.6	14.4	1,264.0	2.4	16.8	1310.4	3.54

AVG = 16.6

Note: Mean amt of fines recovered from SMM centrifuge =
= 16.6g = 1.2 percent of weight total mix.

C3 GRAIN SIZE

DISTRIBUTION DATA

APPENDIX C3. CORE EXTRACTION GRADATIONS   (FILE: MY6SD1.CAL)

SPECIMEN 1-239R							SPECIMEN 2-238						
EXTR WGT AGGR	1,158.0						EXTR WGT AGGR	1,253.7					
WGT IN FILTER	2.2	FA	60				WGT IN FILTER	2.6	FA	53			
WGT IN SOLVENT	11.6	NF	28				WGT IN SOLVENT	21.0	NF	28			
WGT AGGR	---------	MD	6					---------	MD	8			
TOTAL WGT AGGR	1,171.8						TOTAL WGT AGGR	1,277.3					

WGT AGGR SEIVED 1,157.4   WGT AGGR SEIVED 1,253.3

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR	A/B VOLUME	SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR
3/4	0	.0	100.0	0	2.795	.000	3/4	0	.0	100.0	0	2.795
1/2	154.7	13.2	86.8	13	2.795	4.723	1/2	173.3	13.6	86.4	14	2.795
3/8	241.6	20.6	79.4	7	2.798	2.650	3/8	214.4	16.8	83.2	3	2.798
4	343.9	29.3	70.7	9	2.841	3.073	4	445.3	34.9	65.1	18	2.841
8	474.4	40.5	59.5	11	2.826	3.941	8	606.5	47.5	52.5	13	2.826
16	684.8	58.4	41.6	18	2.807	6.397	16	770.1	60.3	39.7	13	2.807
30	842.6	71.9	28.1	13	2.81	4.792	30	920.1	72.0	28.0	12	2.81
50	955.5	81.5	18.5	10	2.808	3.431	50	1032.8	80.9	19.1	9	2.808
100	1049.4	89.6	10.4	8	2.816	2.846	100	1124.5	88.0	12.0	7	2.816
200	1097.8	93.7	6.3	4	2.831	1.459	200	1177.3	92.2	7.8	4	2.831
PAN	1170.1	99.9		6	2.788	2.213	PAN	1275.7	99.9		8	2.788
% ERRO	.15			100		35.525	% ERRO	.13			100	
						2.815						2.818

SPECIMEN 1-244							SPECIMEN 2-238N						
							STA 2+38 had HIGHEST RUT in F-15 LANE						
EXTR WGT AGGR	1,857.8						EXTR WGT AGGR	1,328.9					
WGT IN FILTER	2.5	FA	59				WGT IN FILTER	2.7	FA	48			
WGT IN SOLVENT	22.5	NF	28				WGT IN SOLVENT	13.0	NF	28			
WGT AGGR	---------	MD	6					---------	MD	8			
TOTAL WGT AGGR	1,882.8						TOTAL WGT AGGR	1,344.6					

WGT AGGR SEIVED 1,857.7   WGT AGGR SEIVED 1,328.8

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR	A/B VOLUME	SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR
3/4	0	.0	100.0	0	2.795	.000	3/4	10.8	.8	99.2	1	2.795
1/2	292	15.5	84.5	16	2.795	5.549	1/2	173.2	12.9	87.1	12	2.795
3/8	448.8	23.3	76.2	8	2.798	2.976	3/8	224.4	16.7	83.3	4	2.798
4	590.1	31.3	68.7	8	2.841	2.642	4	527.4	39.2	60.8	23	2.841
8	780.3	41.4	58.5	10	2.826	3.575	8	694.6	51.7	48.3	12	2.826
16	1105.8	58.7	41.3	17	2.807	6.159	16	830.4	61.8	38.2	10	2.807
30	1357.9	72.1	27.9	13	2.81	4.765	30	969	72.1	27.9	10	2.81
50	1539.3	81.8	18.2	10	2.808	3.431	50	1076.3	80.0	20.0	8	2.808
100	1690.4	89.8	10.2	8	2.816	2.850	100	1170.3	87.0	13.0	7	2.816
200	1768.8	93.9	6.1	4	2.831	1.471	200	1231.4	91.6	8.4	5	2.831
PAN	1882.2	100.0		6	2.788	2.160	PAN	1343.2	99.9		8	2.788
% ERRO	.03			100		35.578	% ERRO	.10			100	
						2.811						2.818

APPENDIX C3. CORE EXTRACTION GRADATIONS   (FILE: MY6SD1.CAL)

SPECIMEN 1-246

STA 2+46 had LOWEST RUT in F-4 LANE

					SPECIMEN 2-245RUT			
EXTR WGT AGGR	1,897.4				EXTR WGT AGGR	1,174.8		
WGT IN FILTER	2.7	FA	58		WGT IN FILTER	2.3	FA	54
WGT IN SOLVENT	20.2	MF	28		WGT IN SOLVENT	18.2	MF	31
WGT AGGR	---------	MD	6			---------	MD	9
TOTAL WGT AGGR	1,920.3				TOTAL WGT AGGR	1,195.3		

WGT AGGR SEIVED 1,897.5   WGT AGGR SEIVED

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR	A/B VOLUME	SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR
3/4	0	.0	100.0	0	2.795	.000	3/4	0	.0	100.0	0	2.795
1/2	356.8	18.6	81.4	19	2.795	6.648	1/2	138.1	11.6	88.4	12	2.795
3/8	481.2	25.1	74.9	6	2.798	2.315	3/8	183.3	15.3	84.7	4	2.798
4	611.7	31.9	68.1	7	2.841	2.396	4	402.8	33.7	66.3	18	2.841
8	803.4	41.7	58.3	10	2.826	3.477	8	553	46.3	53.7	13	2.826
16	1132.7	59.0	41.0	17	2.807	6.161	16	701.1	58.7	41.3	12	2.807
30	1388	72.3	27.7	13	2.81	4.731	30	822.5	68.8	31.2	10	2.81
50	1572.2	81.9	18.1	10	2.808	3.416	50	924.3	77.3	22.7	9	2.808
100	1725.6	89.9	10.1	8	2.816	2.837	100	1021.9	85.5	14.5	8	2.816
200	1805.2	94.0	6.0	4	2.831	1.464	200	1086	90.9	9.1	5	2.831
PAN	1919.9	100.0		6	2.788	2.142	PAN	1191.8	99.7		9	2.788
% ERRO	.02			100		35.588	% ERRO	.29			100	
						2.810						2.823

SPECIMEN 1-250   SPECIMEN 2-246N

EXTR WGT AGGR	2,188.6				EXTR WGT AGGR	2,161.0		
WGT IN FILTER	3.4	FA	67		WGT IN FILTER	3.9	FA	52
WGT IN SOLVENT	43.6	NF	36		WGT IN SOLVENT	33.7	NF	30
WGT AGGR	---------	MD	11			---------	MD	9
TOTAL WGT AGGR	2,235.6				TOTAL WGT AGGR	2,198.6		

WGT AGGR SEIVED 2,187.8   WGT AGGR SEIVED

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR	A/B VOLUME	SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR
3/4	0	.0	100.0	0	2.795	.000	3/4	24.2	1.1	98.9	1	2.795
1/2	153.5	6.9	93.1	7	2.795	2.457	1/2	243	11.1	88.9	10	2.795
3/8	234.3	10.5	89.5	4	2.798	1.292	3/8	305	13.9	86.1	3	2.798
4	426.4	19.1	80.9	9	2.841	3.025	4	752.9	34.2	65.8	20	2.841
8	730.3	32.7	67.3	14	2.826	4.810	8	1047.6	47.6	52.4	13	2.826
16	1150.8	51.5	48.5	19	2.807	6.701	16	1326.8	60.3	39.7	13	2.807
30	1440	64.4	35.6	13	2.81	4.604	30	1547.8	70.4	29.6	10	2.81
50	1654.8	74.0	26.0	10	2.808	3.422	50	1722.6	78.3	21.7	8	2.808
100	1838.7	82.2	17.8	8	2.816	2.721	100	1874.9	85.3	14.7	7	2.816
200	1992.6	89.1	10.9	7	2.831	2.432	200est	1992	90.6	9.4	5	2.831
PAN	2225.3	99.5		10	2.788	3.735	PAN	2192.6	99.7		9	2.788
% ERRO	.46			100		35.596	% ERRO	.27			100	
						2.825	(Est value as screen clogged)					2.823

APPENDIX C3. CORE EXTRACTION GRADATIONS   (FILE: MY6SD1.CAL)

SPECIMEN 1-254S

EXTR WGT AGGR   1,521.6
WGT IN FILTER   2.7   FA   59
WGT IN SOLVENT   18.3   MF   32
WGT AGGR   --------- MD   10
TOTAL WGT AGGR 1,542.6

WGT AGGR SEIVED 1,502.1

	RETAINED			A FRACTION	B SGapp	A/B VOLUME
SIEVE	Acc Wgt	%RETD	% PASSING	WGT RETD	AGGR	
3/4	0	.0	100.0	0	2.795	.000
1/2	208.3	13.5	86.5	14	2.795	4.831
3/8	295.8	19.2	80.8	6	2.798	2.027
4	413.7	26.8	73.2	8	2.841	2.690
8	633.2	41.0	59.0	14	2.826	5.035
16	887.4	57.5	42.5	16	2.807	5.871
30	1054.2	68.3	31.7	11	2.81	3.848
50	1182.4	76.6	23.4	8	2.808	2.960
100	1311.3	85.0	15.0	8	2.816	2.967
200	1394.9	90.4	9.6	5	2.831	1.914
PAN	1522.3	98.7		8	2.788	2.962
% ERRO	1.32			99		35.106
						2.849

SPECIMEN 2-248R

EXTR WGT AGGR   1,163.0
WGT IN FILTER   2.4   FA   53
WGT IN SOLVENT   18.6   MF   31
WGT AGGR   --------- MD   9
TOTAL WGT AGGR 1,184.0

WGT AGGR SEIVED

	RETAINED			A FRACTION	B SGapp
SIEVE	Acc Wgt	%RETD	% PASSING	WGT RETD	AGGR
3/4	0	.0	100.0	0	2.795
1/2	129.5	10.9	89.1	11	2.795
3/8	179.6	15.2	84.8	4	2.798
4	418.8	35.4	64.6	20	2.841
8	558.5	47.2	52.8	12	2.826
16	695.2	58.7	41.3	12	2.807
30	818.2	69.1	30.9	10	2.81
50	921.8	77.9	22.1	9	2.808
100	1019.5	86.1	13.9	8	2.816
200	1083	91.5	8.5	5	2.831
PAN	1182.9	99.9		8	2.788
% ERRO	.09			100	
					2.818

SPECIMEN 1-258

EXTR WGT AGGR   2,202.0
WGT IN FILTER   2.7   FA   65
WGT IN SOLVENT   30.4   MF   34
WGT AGGR   --------- MD   10
TOTAL WGT AGGR 2,235.1

WGT AGGR SEIVED 2,200.9

	RETAINED			A FRACTION	B SGapp	A/B VOLUME
SIEVE	Acc Wgt	%RETD	% PASSING	WGT RETD	AGGR	
3/4	10.9	.5	99.5	0	2.795	.174
1/2	171.8	7.7	92.3	7	2.795	2.576
3/8	286.2	12.8	87.2	5	2.798	1.829
4	476.1	21.3	78.7	8	2.841	2.991
8	790.9	35.4	64.6	14	2.826	4.984
16	1202.8	53.8	46.2	18	2.807	6.565
30	1471.3	65.8	34.2	12	2.81	4.275
50	1679.3	75.1	24.9	9	2.808	3.314
100	1891.9	84.6	15.4	10	2.816	3.378
200	2021.5	90.4	9.6	6	2.831	2.048
PAN	2232.1	99.9		9	2.788	3.380
% ERRO	.13			100		35.514
						2.816

SPECIMEN 2-254
STA 2+54 had LOWEST RUT IN F-15 LANE

EXTR WGT AGGR   2,096.9
WGT IN FILTER   3.0   FA   52
WGT IN SOLVENT   18.3   MF   29
WGT AGGR   --------- MD   8
TOTAL WGT AGGR 2,118.2

WGT AGGR SEIVED 2,095.7

	RETAINED			A FRACTION	B SGapp
SIEVE	Acc Wgt	%RETD	% PASSING	WGT RETD	AGGR
3/4	0	.0	100.0	0	2.795
1/2	237.27	11.2	88.8	11	2.795
3/8	337.57	15.9	84.1	5	2.798
4	726.2	34.3	65.7	18	2.841
8	1016.89	48.0	52.0	14	2.826
16	1273.86	60.1	39.9	12	2.807
30	1494.99	70.6	29.4	10	2.81
50	1665.52	78.6	21.4	8	2.808
100	1836.67	86.7	13.3	8	2.816
200	1939.97	91.6	8.4	5	2.831
PAN	2107.8	99.5		8	2.788
% ERRO	.49			100	
					2.829

APPENDIX C3. CORE EXTRACTION GRADATIONS   (FILE: MYGSD1.CAL)

SPECIMEN 1-258N (3T7-4)

EXTR WGT AGGR	1,276.7		
WGT IN FILTER	2.9	FA	55
WGT IN SOLVENT	15.8	MF	29
WGT AGGR	--------	MD	8
TOTAL WGT AGGR	1,295.4		

WGT AGGR SEIVED 1,276.1

	RETAINED			A FRACTION	B SGapp	A/B VOLUME
SIEVE	Acc Wgt	ZRETD	Z PASSING	WGT RETD	AGGR	
3/4	11.8	.9	99.1	1	2.795	.326
1/2	274.9	21.2	78.8	20	2.795	7.267
3/8	355.4	27.4	72.6	6	2.798	2.221
4	437.5	33.8	66.2	6	2.841	2.231
8	588.6	45.4	54.6	12	2.826	4.128
16	792.8	61.2	38.8	16	2.807	5.616
30	925.2	71.4	28.6	10	2.81	3.637
50	1025.9	79.2	20.8	8	2.808	2.768
100	1126.8	87.0	13.0	8	2.816	2.766
200	1192.4	92.0	8.0	5	2.831	1.789
PAN	1293.7	99.9		8	2.788	2.805
Z ERRO	.13			100		35.553
						2.813

SPECIMEN 2-254N

EXTR WGT AGGR	1,518.7		
WGT IN FILTER	3.0	FA	48
WGT IN SOLVENT	21.1	MF	27
	--------	MD	8
TOTAL WGT AGGR	1,542.8		

WGT AGGR SEIVED 1,518.0

	RETAINED			A FRACTION	B SGapp
SIEVE	Acc Wgt	ZRETD	Z PASSING	WGT RETD	AGGR
3/4	0	.0	100.0	0	2.795
1/2	214.6	13.9	86.1	14	2.795
3/8	321.7	20.9	79.1	7	2.798
4	617.9	40.1	59.9	19	2.841
8	799.8	51.8	48.2	12	2.826
16	977.3	63.3	36.7	12	2.807
30	1121.4	72.7	27.3	9	2.81
50	1235.2	80.1	19.9	7	2.808
100	1334.6	86.5	13.5	6	2.816
200	1418.9	92.0	8.0	5	2.831
PAN	1540.2	99.8		8	2.788
Z ERRO	.17			100	
					2.819

SPECIMEN 1-260

EXTR WGT AGGR	1,876.7		
WGT IN FILTER	3.0	FA	55
WGT IN SOLVENT	16.8	MF	28
WGT AGGR	--------	MD	7
TOTAL WGT AGGR	1,896.5		

WGT AGGR SEIVED 1,877.1

	RETAINED			A FRACTION	B SGapp	A/B VOLUME
SIEVE	Acc Wgt	ZRETD	Z PASSING	WGT RETD	AGGR	
3/4	0	.0	100.0	0	2.795	.000
1/2	344.7	18.2	81.8	18	2.795	6.503
3/8	476.9	25.1	74.9	7	2.798	2.491
4	605.6	31.9	68.1	7	2.841	2.389
8	847.9	44.7	55.3	13	2.826	4.521
16	1182.2	62.3	37.7	18	2.807	6.280
30	1372.9	72.4	27.6	10	2.81	3.578
50	1517.8	80.0	20.0	8	2.808	2.721
100	1668.3	88.0	12.0	8	2.816	2.818
200	1762.2	92.9	7.1	5	2.831	1.749
PAN	1895.2	99.9		7	2.788	2.515
Z ERRO	.07			100		35.565
						2.812

SPECIMEN 2-256X

EXTR WGT AGGR	1,274.4		
WGT IN FILTER	2.6	FA	51
WGT IN SOLVENT	18.3	MF	28
	--------	MD	8
TOTAL WGT AGGR	1,295.3		

WGT AGGR SEIVED 1,274.4

	RETAINED			A FRACTION	B SGapp
SIEVE	Acc Wgt	ZRETD	Z PASSING	WGT RETD	AGGR
3/4	0	.0	100.0	0	2.795
1/2	133.2	10.3	89.7	10	2.795
3/8	189.8	14.7	85.3	4	2.798
4	478.1	36.9	63.1	22	2.841
8	641.1	49.5	50.5	13	2.826
16	797.4	61.6	38.4	12	2.807
30	931	71.9	28.1	10	2.81
50	1035.8	80.0	20.0	8	2.808
100	1132.3	87.4	12.6	7	2.816
200	1192.1	92.0	8.0	5	2.831
PAN	1293.3	99.8		8	2.788
Z ERRO	.15			100	
					2.820

APPENDIX C3. CORE EXTRACTION GRADATIONS   (FILE: MY6SD1.CAL)

SPECIMEN 1-264

EXTR WGT AGGR	1,926.4			
WGT IN FILTER	2.9	FA	61	
WGT IN SOLVENT	31.7	NF	31	
WGT AGGR	---------	MD	8	
TOTAL WGT AGGR	1,961.0			

WGT AGGR SEIVED 1,926.2

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR	A/B VOLUME
3/4	0	.0	100.0	0	2.795	.000
1/2	256.4	13.1	86.9	13	2.795	4.678
3/8	348	17.7	82.3	5	2.798	1.669
4	492.5	25.1	74.9	7	2.841	2.594
8	771.6	39.3	60.7	14	2.826	5.036
16	1147.5	58.5	41.5	19	2.807	6.829
30	1359.1	69.3	30.7	11	2.81	3.840
50	1526.9	77.9	22.1	9	2.808	3.047
100	1698.6	86.6	13.4	9	2.816	3.109
200	1803.6	92.0	8.0	5	2.831	1.891
PAN	1959.4	99.9		8	2.788	2.850
% ERRO	.08			100		35.544
						2.813

SPECIMEN 2-256R

EXTR WGT AGGR	1,608.1			
WGT IN FILTER	4.1	FA	48	
WGT IN SOLVENT	22.1	NF	27	
	---------	MD	8	
TOTAL WGT AGGR	1,634.3			

WGT AGGR SEIVED 1,608.4

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR
3/4	0	.0	100.0	0	2.795
1/2	242	14.8	85.2	15	2.795
3/8	353.7	21.6	78.4	7	2.798
4	656.1	40.1	59.9	19	2.841
8	847.8	51.9	48.1	12	2.826
16	1028.7	62.9	37.1	11	2.807
30	1185.7	72.6	27.4	10	2.81
50	1310.1	80.2	19.8	8	2.808
100	1425.3	87.2	12.8	7	2.816
200	1501.8	91.9	8.1	5	2.831
PAN	1632	99.9		8	2.788
% ERRO	.14			100	
					2.818

SPECIMEN 1-264N

STA 1-264 HAD HIGHEST RUT in F-4 LANE

EXTR WGT AGGR	1,373.5			
WGT IN FILTER	2.5	FA	61	
WGT IN SOLVENT	17.0	NF	30	
WGT AGGR	---------	MD	8	
TOTAL WGT AGGR	1,393.0			

WGT AGGR SEIVED 1,373.8

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR	A/B VOLUME
3/4	0	.0	100.0	0	2.795	.000
1/2	204.2	14.7	85.3	15	2.795	5.245
3/8	275.5	19.8	80.2	5	2.798	1.829
4	374.3	26.9	73.1	7	2.841	2.497
8	545.3	39.1	60.9	12	2.826	4.344
16	823.6	59.1	40.9	20	2.807	7.117
30	979.3	70.3	29.7	11	2.81	3.978
50	1095.4	78.6	21.4	8	2.808	2.968
100	1203.4	86.4	13.6	8	2.816	2.753
200	1288	92.5	7.5	6	2.831	2.145
PAN	1392.2	99.9		7	2.788	2.683
% ERRO	.06			100		35.559
						2.812

SPECIMEN 2-260N

EXTR WGT AGGR	643.8			
WGT IN FILTER	2.4	FA	42	
WGT IN SOLVENT	8.9	NF	22	
	---------	MD	7	
TOTAL WGT AGGR	655.1			

WGT AGGR SEIVED 643.3

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR
3/4	0	.0	100.0	0	2.795
1/2	137.1	20.9	79.1	21	2.795
3/8	188.1	28.7	71.3	8	2.798
4	312.5	47.7	52.3	19	2.841
8	381.4	58.2	41.8	11	2.826
16	457.2	69.8	30.2	12	2.807
30	510.7	78.0	22.0	8	2.81
50	550.2	84.0	16.0	6	2.808
100	582.8	89.0	11.0	5	2.816
200	609.5	93.0	7.0	4	2.831
PAN	653.3	99.7		7	2.788
% ERRO	.27			100	
					2.820

APPENDIX C3. CORE EXTRACTION GRADATIONS   (FILE: MYGSD1.CAL)

SPECIMEN 1-264S

EXTR WGT AGGR   1,411.8
WGT IN FILTER   2.7   FA   60
WGT IN SOLVENT   15.9   MF   30
WGT AGGR   --------- MD   8
TOTAL WGT AGGR   1,430.4

WGT AGGR SEIVED   1,411.6

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR	A/B VOLUME
3/4	0	.0	100.0	0	2.795	.000
1/2	179.9	12.6	87.4	13	2.795	4.500
3/8	266.6	18.6	81.4	6	2.798	2.166
4	274.2	19.2	80.8	1	2.841	.187
8	571.6	40.0	60.0	21	2.826	7.357
16	843	58.9	41.1	19	2.807	6.759
30	995	69.6	30.4	11	2.81	3.782
50	1113	77.8	22.2	8	2.808	2.938
100	1237.3	86.5	13.5	9	2.816	3.086
200	1317	92.1	7.9	6	2.831	1.968
PAN	1429.2	99.9		8	2.788	2.813
% ERRO	.08			100		35.557
						2.812

SPECIMEN 2-260S (1T6-9)

EXTR WGT AGGR   1,156.6
WGT IN FILTER   2.7   FA   42
WGT IN SOLVENT   16.6   MF   24
                --------- MD   7
TOTAL WGT AGGR   1,175.9

WGT AGGR SEIVED   1,155.9

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR
3/4	0	.0	100.0	0	2.795
1/2	250.2	21.3	78.7	21	2.795
3/8	329.7	28.0	72.0	7	2.798
4	567.2	48.2	51.8	20	2.841
8	685.1	58.3	41.7	10	2.826
16	797.3	67.8	32.2	10	2.807
30	895.6	76.2	23.8	8	2.81
50	973.3	82.8	17.2	7	2.808
100	1043.6	88.7	11.3	6	2.816
200	1089.5	92.7	7.3	4	2.831
PAN	1174	99.8		7	2.788
% ERRO	.16			100	
					2.817

SPECIMEN 1-268

EXTR WGT AGGR   2,281.2
WGT IN FILTER   3.7   FA   45
WGT IN SOLVENT   36.6   MF   23
WGT AGGR   --------- MD   9
TOTAL WGT AGGR   2,321.5

WGT AGGR SEIVED   2,280.6

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR	A/B VOLUME
3/4	0	.0	100.0	0	2.795	.000
1/2	307.5	13.2	86.8	13	2.795	4.739
3/8	465.9	20.1	79.9	7	2.798	2.439
4	795.4	34.3	65.7	14	2.841	4.996
8	1276.2	55.0	45.0	21	2.826	7.329
16	1567.9	67.5	32.5	13	2.807	4.476
30	1783.9	76.8	23.2	9	2.81	3.311
50	1991.6	85.8	14.2	9	2.808	3.186
100	2070	89.2	10.8	3	2.816	1.199
200	2117	91.2	8.8	2	2.831	.715
PAN	2318.9	99.9		9	2.788	3.119
% ERRO	.11			100		35.510
						2.816

SPECIMEN 2-264

EXTR WGT AGGR   1,720.1
WGT IN FILTER   3.0   FA   38
WGT IN SOLVENT   15.0   MF   19
                --------- MD   6
TOTAL WGT AGGR   1,738.1

WGT AGGR SEIVED

SIEVE	RETAINED Acc Wgt	%RETD	% PASSING	A FRACTION WGT RETD	B SGapp AGGR
3/4	24.4	1.4	98.6	1	2.795
1/2	370.5	21.3	78.7	20	2.795
3/8	519.7	29.9	70.1	9	2.798
4	884.5	50.9	49.1	21	2.841
8	1081.9	62.2	37.8	11	2.826
16	1280.2	73.7	26.3	11	2.807
30	1411.2	81.2	18.8	8	2.81
50	1502.9	86.5	13.5	5	2.808
100	1580.3	90.9	9.1	4	2.816
200	1631.5	93.9	6.1	3	2.831
PAN	1736.4	99.9		6	2.788
% ERRO	.10			100	
					2.816

APPENDIX C3. CORE EXTRACTION GRADATIONS   (FILE: NYGSD1.CAL)

SPECIMEN 2-268

EXTR WGT AGGR	1,247.2		
WGT IN FILTER	2.4	FA	45
WGT IN SOLVENT	14.4	NF	21
	--------	MD	6
TOTAL WGT AGGR	1,264.0		

WGT AGGR SEIVED

	RETAINED			A FRACTION	B SGapp
SIEVE	Acc Wgt	%RETD	% PASSING	WGT RETD	AGGR
3/4	11.1	.9	99.1	1	2.795
1/2	349.1	27.6	72.4	27	2.795
3/8	422.8	33.4	66.6	6	2.798
4	588.4	46.6	53.4	13	2.841
8	699.2	55.3	44.7	9	2.826
16	878	69.5	30.5	14	2.807
30	998.2	79.0	21.0	10	2.81
50	1082.6	85.6	14.4	7	2.808
100	1147.1	90.8	9.2	5	2.816
200	1194	94.5	5.5	4	2.831
PAN	1263.3	99.9		5	2.788
% ERRO	.06			100	
					2.811

APPENDIX D

JOB MIX FORMULA

STABILITY (lbs)

PERCENT BINDER (WGT of MIX)
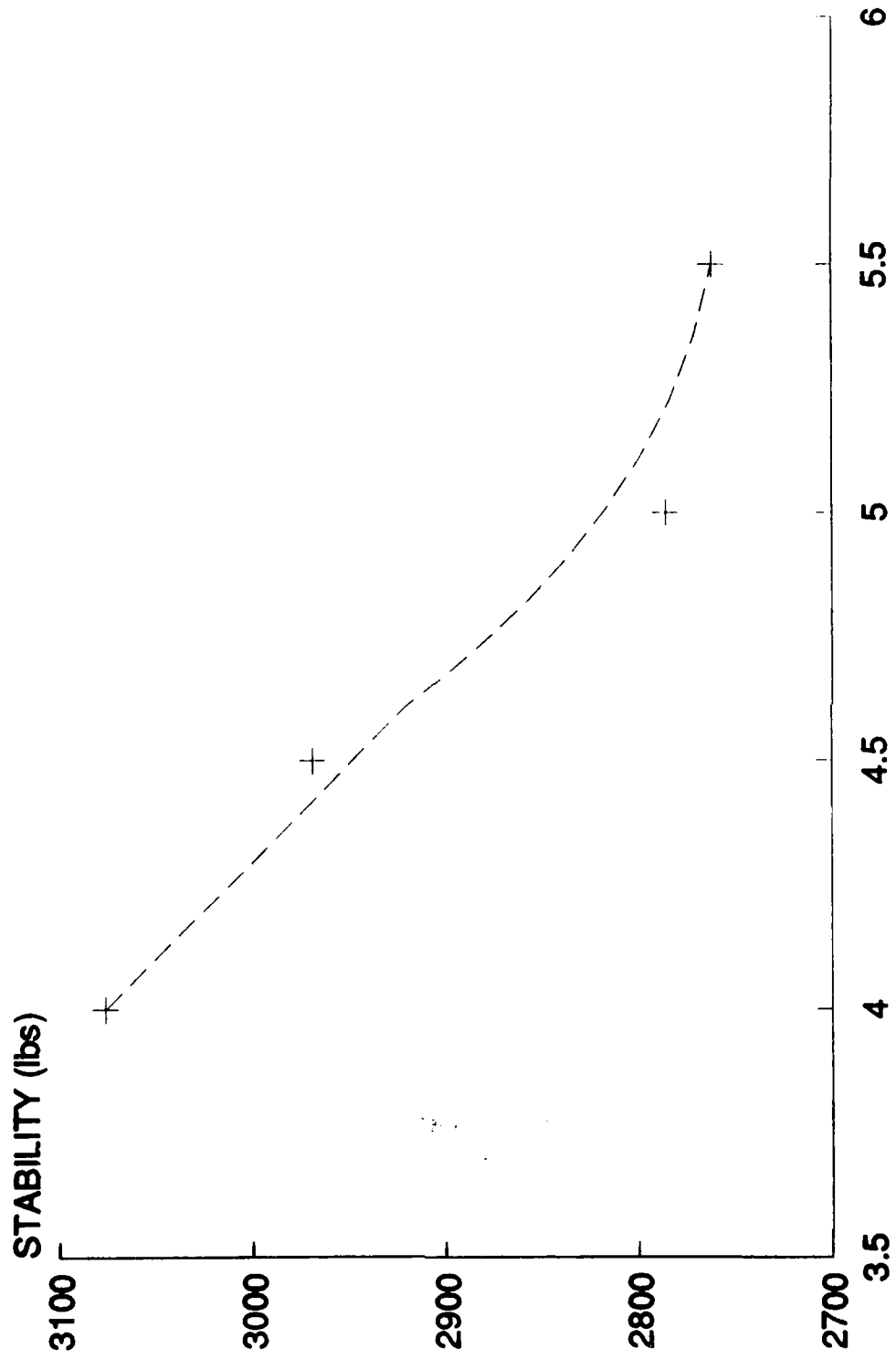
APPENDIX D1. MIX DESIGN RESULTS FROM PAVLOVICH & STONEX (5)

FLOW (UNITS)

PERCENT BINDER (WGT of MIX)
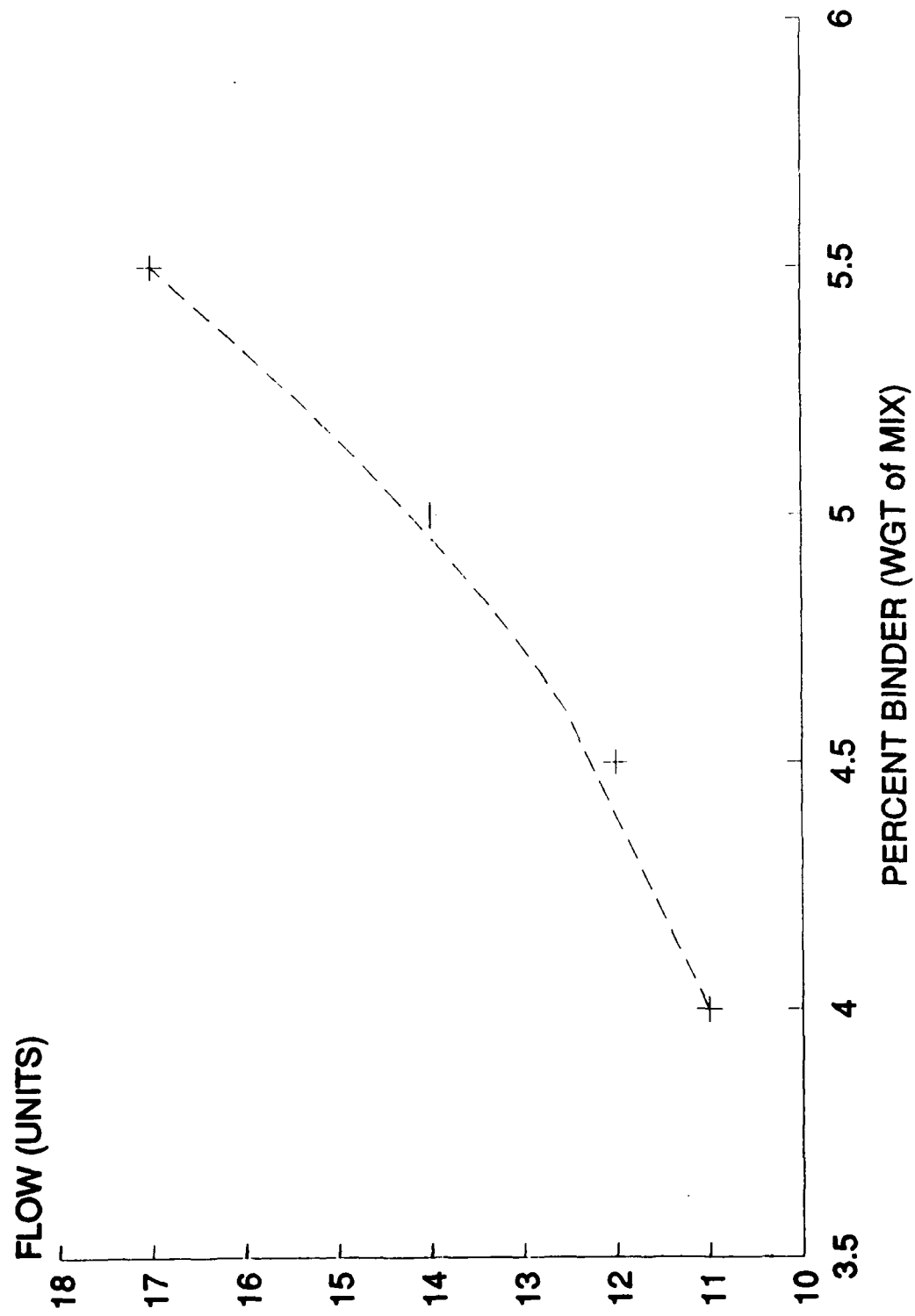
APPENDIX D2. MIX DESIGN RESULTS FROM PAVLOVICH & STONEX (5)

UNIT WEIGHT (PCF)

PERCENT BINDER (WGT of MIX)
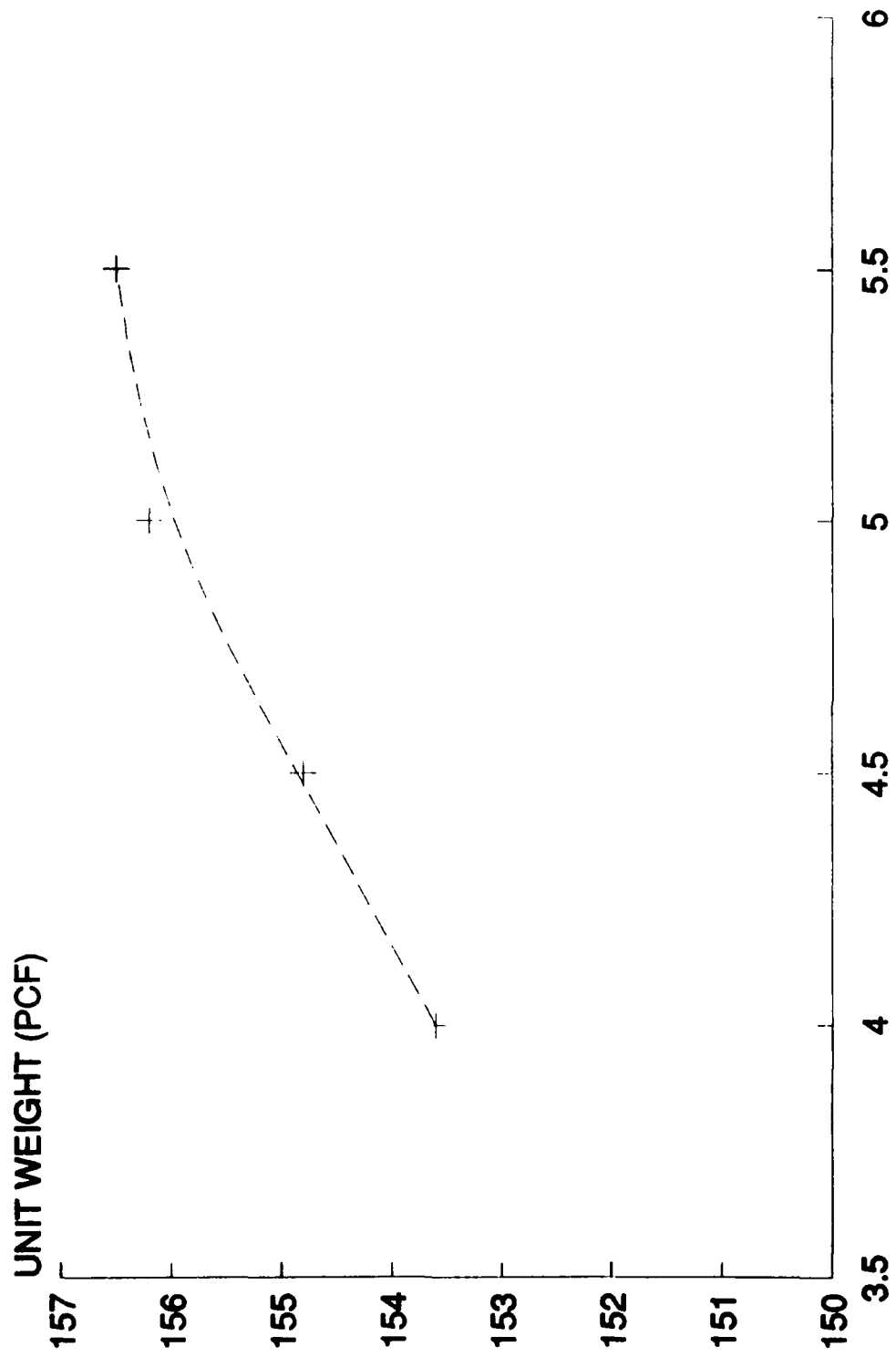
APPENDIX D3. MIX DESIGN RESULTS FROM PAVLOVICH & STONEX (5)

PERCENT AIR VOIDS

PERCENT BINDER (WGT of MIX)
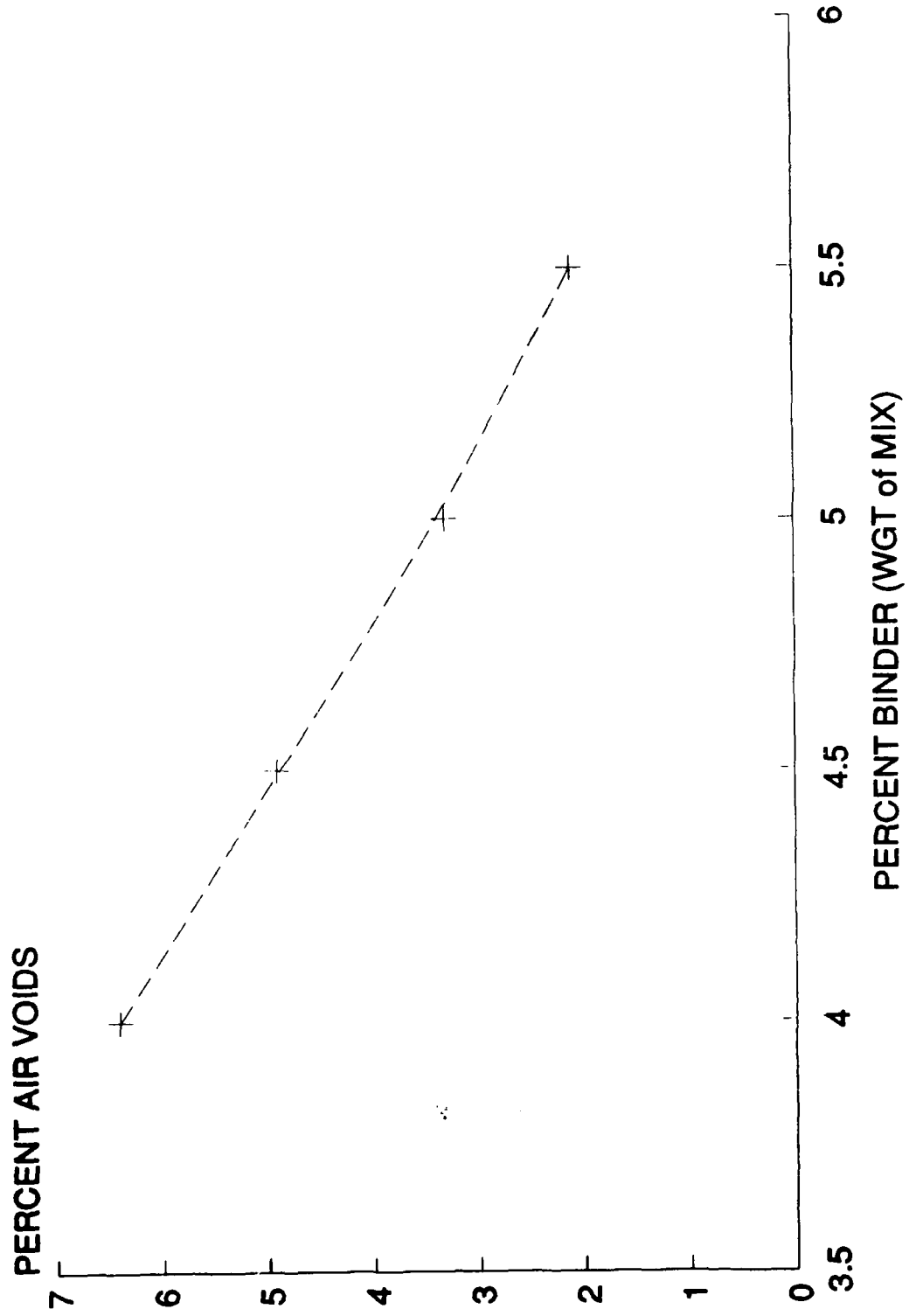
APPENDIX D4. MIX DESIGN RESULTS FROM PAVLOVICH & STONEX (5)

PERCENT VOIDS FILLED

PERCENT BINDER (WGT of MIX)
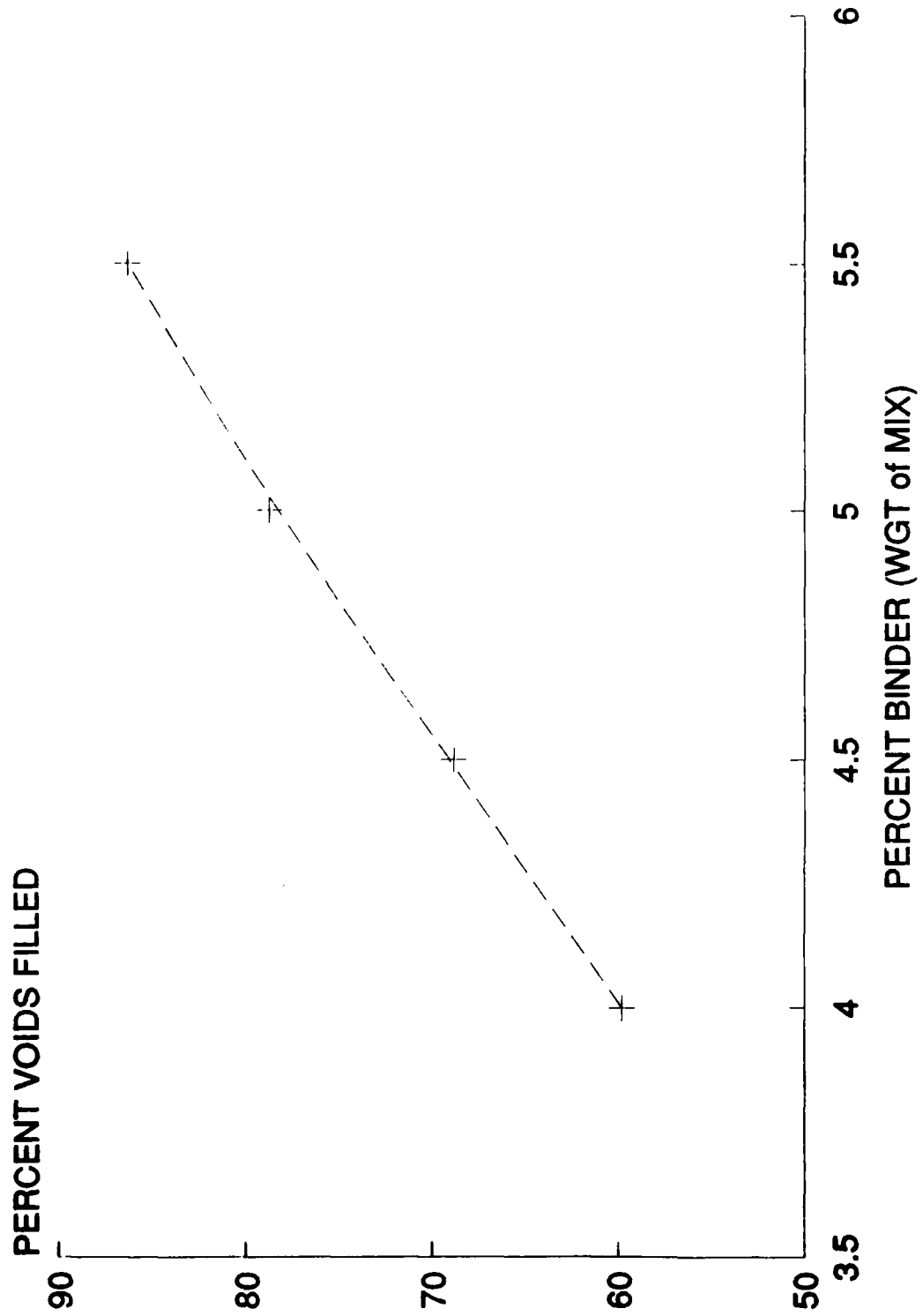
APPENDIX D5. MIX DESIGN RESULTS FROM PAVLOVICH & STONEX (5)

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